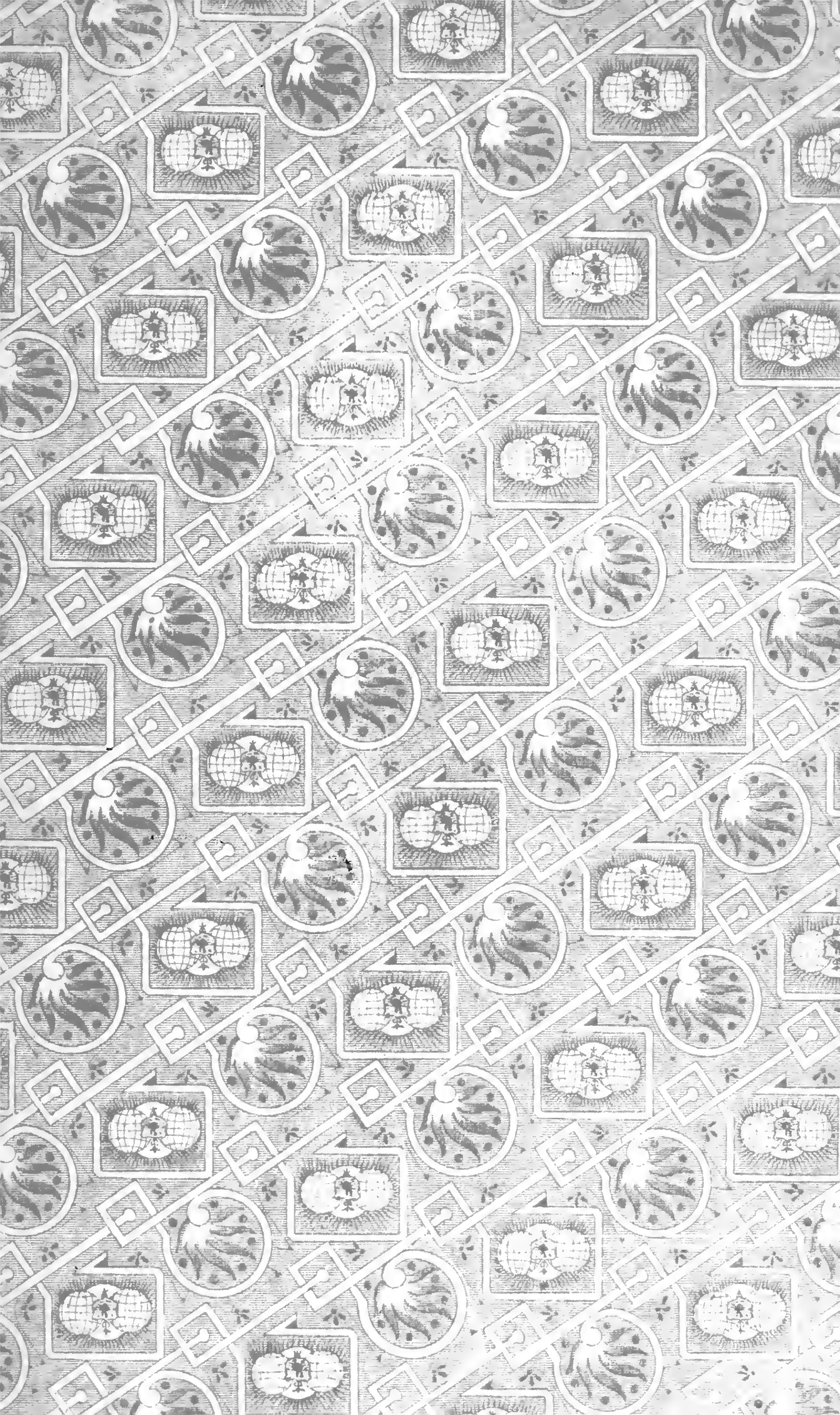

ESSAY

ON

MEDICAL PNEUMATOLOGY:

A

Physiological, Clinical, and Therapeutic Investigation of the Gases.

BY

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TRANSLATED, WITH NOTES, ADDITIONS, AND OMISSIONS,

BY

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ILLUSTRATED WITH FINE WOOD-ENGRAVINGS.

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TO

PROFESSOR TROUSSEAU,

WITH

THE REVERENTIAL HOMAGE OF THE AUTHOR,

Demarquay.

AUTHOR'S PREFACE.

THIS work, issued under the title of "Essay on Pneumatology," has nothing in common, except its title, with the work of Combalusier, published in 1747, and entitled, "Pneumato-Pathologia Seu Fractatus de Flatulentis Humani Corporis Affectibus." As its title indicates, this latter work includes only the subject of gastro-intestinal pneumatosis, and in this direction some useful observations may still be derived. In our essay the object has been to study those diseases in which the gases play a certain rôle, as the pneumatoses and the emphysemas,* and to study the applications which may be made of the gases in therapeutics. At the period when Priestley and Lavoisier made their immortal discoveries, oxygen and carbonic acid became the objects of very interesting and important investigations on the part of physicians and physiologists. The latter sought, in the study of these gases, a new cause of diseases. while the former, on the contrary, hoped to find new means of treatment. Hence, for Beddoes, who was much occupied in the application of the gases to therapeutics, there were diseases with excess of oxygen; for example, he imagined that *phthisis* is a disease in which there is a predominance of this gas in the blood. Rollo went still further than Beddoes. He divided diseases into two great classes: one with excess of "vital air," as diabetes; and the other with a dearth of this element, such as scorbutus. Baumès, professor at Montpellier, in a work published in 1798 under the title of "Essai d'Un Systeme Chimique de la Science de l'Homme," classified diseases as Oxygeneses, Calorineses, Hydrogeneses, and Azoteneses, assuming that oxygen, caloric hydrogen, or nitrogen, to a greater or less extent,

* The chapter on Emphysema has been omitted, as of less interest than other portions of the work.—TRANS.

were the causes of all pathologic conditions. Fourcroy himself, as we have shown in that part of the work devoted to the history of oxygen, also committed himself to a series of hypotheses on this point, and, singular fact, while these authors dwelt on the influence of the gases as a pathogenic cause, not one of them thought to try an experiment to prove that the blood actually contains certain gases, either in a free state or in combination. It required the labors of Magnus to demonstrate a fact on which, long before him, a multitude of hypotheses had been based. In 1829 M. Foderé, professor at Strasburg, had also published an "Essai de Pneumatologie, Theorique et Pratique." But this work, evolved from a purely vitalistic point of view, is practical only in name. Neither observation nor physiological experimentation served as a foundation for the studies to which the author whom we have just cited devoted himself. In 1834 Baumès wrote a more interesting brochure, entitled "Traitè des Maladies Venteuses." In this work, as in that of Combalusier, only the subject of gastro-intestinal pneumatosis is investigated.

In the work which we now publish we propose, as we have already stated, to study those diseases in which there is a production of gas, and to follow this with an account of the physiologic and therapeutic experiments which we have made on this subject. The beginning of these investigations dates back to 1856. Undertaken in connection with M. Leconte,* chief pharmacist of the Maison Municipale de Santè, they had as their object:—

1. To study the chemical and physiological action of gases injected into closed cavities, and into the healthy tissues of animals.

2. To learn the influence of gases on the reparation of tendons divided by subcutaneous section, and to illustrate, in as complete a manner as possible, the theory of the cicatrization of wounds following these operations.

3. To make therapeutic application to exposed wounds of

* Recherches sur les Gaz., vol. i, 1859 ; vol. ii, 1862 ; Archives Gén. de Méd.

the action of gases which shall have shown a manifest influence in promoting cicatrization.

All these investigations, made in common, have been published in the "Comptes Rendus of the Academy of Sciences" during the period from 1857 to 1864, and are carefully summarized in this work. But having followed the study of the gases from merely historical, physiological, and therapeutical aspects, we were quickly convinced that there still remained a fruitful mine to be explored.

Encouraged in these investigations by the kindly interest manifested by several of our teachers, and by M. Velpeau in particular, we have bent all our efforts toward the demonstration of practical results.

There are still some points of the subject to be cleared up, which physiology and pathology alone, without the aid of chemistry, are not able to elucidate. We hope that future investigators, better versed in the study of the physical sciences, will continue this subject, as yet scarcely outlined. We limit ourselves, for the present, to merely indicating the plan and order we have pursued in this account of our investigations.

Our work is divided into two parts: the first, physiological and pathological; the second, physiological and therapeutic.

We have sought, by physiological experiments, to elucidate certain points relative to this important subject.

How many times during the progress of these investigations have we regretted that the gases of the blood have been studied wholly from a physiological point of view! It is very certain that any physician who will undertake investigations concerning the gases of the blood analogous to those of MM. Andral and Gavarret, who have laid the foundations of hæmatology, will, we are sure, arrive at interesting results. It is quite evident that if we cause an animal, which we have encased in an impermeable covering, to die of asphyxiation, we ought to find in its blood, as well as in that of a man attacked by an extensive erysipelas, a scarlatina, or confluent small-pox,

very decided modifications as regards the gases of the blood,—oxygen, nitrogen, and carbonic acid,—since in these instances the functions of the skin are necessarily very much modified, or interfered with.

In the second part of the work, devoted to the physiological and therapeutic study of the gases, we have particularly studied oxygen, carbonic acid, nitrogen, protoxide of nitrogen, and hydrogen, considering that these fluids nearly all enter into the composition of the atmosphere, and that of water, and form the nutritive elements of our food. As regards the statement of therapeutic facts relative to oxygen and carbonic acid, we have endeavored, as far as possible, to corroborate our practice by the experiments of other observers, who, at the end of the last century and the beginning of this, pursued the same line of inquiry. We have also made it a point to report the practical results obtained by those of our *confrères* who have, in the latter period, made therapeutic use of the gases. We refer to Professor Trousseau and our honorable *confrères*, Monod, Nonat, Heroè de Lavaur, Saint-Vel, Foley, etc.

In closing this introduction we extend our acknowledgments to MM. Lavaysse, Méric, Voelker, Flurin, Lemoine, Sicard, Cosmao-Dumenez, Poinceau Revillod, Dubourg, R. Blache, and Boucher, all former pupils of the Maison de Santè, for the zeal with which they assisted in our numerous experiments. We desire to especially thank our young friend, Cyr, for the intelligent researches he has made for us in English works, and who has rendered such valuable aid in the preparation of this volume.

TRANSLATOR'S PREFACE.

The use of oxygen as a therapeutic agent has been steadily increasing in this country for the past twenty years, notwithstanding the fact that the gas has been for the most part indifferently prepared and more indifferently exhibited. No American practitioner has devoted to it any approach toward scientific and thorough investigation, and all our experimenters, up to a very recent date, have used it chiefly from an empirical stand-point.

So far as he can learn, the writer contributed to the *Chicago Medical Journal** the first American paper on the subject.

In 1870 Dr. A. H. Smith, of New York, read a prize essay before the Alumni Association of the College of Physicians and Surgeons, which was afterward published in the *New York Medical Journal*, and reprinted in pamphlet form.

Dr. Smith's paper gave a very comprehensive summary of the subject up to that date, including his own experience and that of others, but he did not attempt any exhaustive study. Since that time interest has increased, experimenters have multiplied, and from time to time papers have appeared in the various medical journals. The only volume yet published in this country appeared in 1887 from the pen of Dr. C. E. Ehinger.†

Dr. Ehinger gave a partial compend of existing literature, with some notes and experiences of his own, but modestly disclaimed originality, and attempted no thorough or scientific study.

It is rather remarkable that even in this enterprising age no writer in this country has availed himself of the work done more than twenty years ago by Demarquay and others in France.

Cursory reference to Demarquay was made by the authors

* "Superoxygenation as a Therapeutic Measure," Chicago Medical Journal, February and March, 1869.

† On Oxygen as a Therapeutic Agent. 8vo, pp. 160. Chicago, 1887.

of the earlier essays mentioned, but subsequent writers have contented themselves with parrot-like repetitions of these, none of them going to the original for further material. The French investigators were not slow to avail themselves of whatever their English predecessors had accomplished or written, and American readers will doubtless feel a tinge of humiliation when they learn through this French professor that the earliest essay on nitrogen, in its physiologic and therapeutic relations, was by an American [Saltonstall, see page 196]. Again, it is a fact that some of the recent contributions of American authors on the subject of the gases—particularly oxygen—in therapeutics have been first seen by American writers on the same subject in a foreign language. The writer not long since even took the trouble to translate from the French some interesting conclusions, only to find them at the end accredited to an American journal! This is not flattering to our national pride. Surely, if we can do nothing to add to it, we ought at least to keep ourselves informed of the progress of our neighbors across the ocean. It is for this reason that a translation of the more pertinent portion of Demarquay's work, originally reported to the Academy of Medicine of Paris and published in 1866, is brought before the American profession.

The complete work of Demarquay consists of eight hundred and sixty-one octavo pages, and is divided into three principal parts. The most practical portion of Part First, treating of the Pneumatoses, is given herewith. Part Second, on Emphysema, is entirely omitted, as being of a more discursive nature and of less practical value at the present moment. Nevertheless, it contains much that is interesting.

Of Part Third, the first four chapters, chiefly devoted to therapeutic experiments with carbonic acid, are also omitted.

In the chapters on Oxygen the reports of cases have in many instances been condensed, to avoid giving space to unessential details and prolix repetitions.

It is hoped that the practical value of the work has thus

been enhanced, and that nothing of vital importance to the general reader has been omitted.

The complete volume, in the opinion of the translator, would have been too bulky, and in some portions too much given to speculative discourse, for profitable reproduction.

The work of translating has been done in the midst of many and distracting duties, and will not, therefore, be found above criticism; but it has been the aim to select only such of the author's laborious and painstaking work as shall prove of practical value to American readers; and to this has been added such notes, comments and suggestions as the writer's personal experience and the recent progress of pneumatological science seem to demand.

S. S. W.

NEW YORK, May, 1889.

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ESSAY

ON

MEDICAL PNEUMATOLOGY.

CHAPTER I.

STUDY OF THE GASES OF THE BLOOD IN THEIR PHYSIOLOGICAL CONDITION.

THE history of the gases of the blood has been for two centuries the subject of numerous and interesting studies on the part of chemists and physiologists. Mayow was the first who, about the year 1674, demonstrated the presence of an aeriform fluid in the circulation; but his discovery, so important as regards the deductions which should have followed it, soon fell into oblivion.

At the beginning of the nineteenth century Sir Humphry Davy fixed attention anew on this subject, and obtained "from twelve ounces of blood 1.8 cubic inches of gas, consisting of 1.1 cubic inches of carbonic acid and 0.7 cubic inch of oxygen."*

Some years later, about 1815, Vogel, in Germany, also recognized the presence of carbonic acid in the blood.

"I introduced," said he, "some fresh ox-blood into a flask, furnished with a bent tube which communicated with a glass tumbler filled with lime-water, placing the whole apparatus under the receiver of a pneumatic apparatus. On producing a vacuum the blood rose wonderfully and formed a considerable foam. Much carbonic acid gas was released from the outset, and the lime-water was at once perceptibly clouded. From the foregoing it is evident that the blood in its freshest state contains carbonic acid already formed, and that the release of this acid is not due to the decomposition of certain primary constituents, as some chemists have thought." †

Vogel's experiments, although interesting in a historical

* Burdach, Traitè de Phys., t. vi, p. 84.
† Annales de Chimie et de Physique, t. xciii, p. 74, Annee 1815.

point of view, were not really as conclusive as he seemed to think them. The blood he used, not having been taken directly from the circulation of the animal from which it was derived, while under the pneumatic receiver, must have been at least several minutes in contact with atmospheric air. Now, we know with what rapidity and with what facility blood absorbs the gases of the atmosphere. Hence, it is not proved that the carbonic acid gas of the foregoing experiment was not the result of the action of the air on this liquid.

John Davy denies that carbonic acid gas is given off from the blood, except in case of putrefaction, and affirms that this acid does not exist in fresh blood.*

Mitscherlich, Gmelin, Tiedemann, and others do not admit the existence of gas in the sanguineous system at all, while its presence is admitted by Brande, Hoffmann, and Stevens, in England. Thus it appears that the question we are now discussing has been the subject of the greatest controversies. We must come down to the year 1837 to find it settled beyond doubt by the beautiful experiments of Magnus.†

It would require too much space to describe here the ingenious apparatus used by this observer to demonstrate the existence of gases in the blood. We will content ourselves by stating that the blood used was procured by means of a flexible and impermeable tube, directly from the primitive carotid artery, or from the internal jugular vein of the animal under experiment, according to whether he wished to experiment with arterial or venous blood. Thus the blood was perfectly excluded from contact with atmospheric air. For the sake of still greater accuracy the first portions of blood which passed the tubes were rejected. By operating in this manner this eminent physiologist arrived at the following conclusion:—

The proportion of gases in the blood is always equal to one-tenth and sometimes rises to one-eighth of the volume of the blood employed.

However, as he remarked, there is represented in such percentage but a portion of the total gases in any given volume of blood, since every time the experiment is repeated with the same blood a further quantity of gas is obtained,—scanty, it is true, but quite appreciable.

* Burdach, *op. cit.*, vi, p. 84.
† Annales de Chimie et de Physique, t. xlv, 1837.

This peculiar circumstance has even obliged him, in order to have a means of comparing the results obtained, one with the other, to always allow the blood in the apparatus to remain there a certain definite time before collecting the gases, viz., three hours for each experiment.

Magnus further determined that the gaseous bodies found in normal blood, whether arterial or venous, are three in number: *oxygen*, *azote* (nitrogen), and *carbonic acid*. The relative proportions of these, as found in venous and arterial blood, was far from being uniform. In fact, he demonstrated that in venous blood oxygen and carbonic acid gas exist in proportion as 1 to 3, or 1 to 4, while in arterial blood the proportion changes to 1 to 2, and sometimes to equal parts. The relation between the nitrogen and oxygen or the nitrogen and carbonic acid in the two kinds of blood, as he found, does not maintain a constant ratio. Sometimes its quantity is greater in one, and sometimes in the other. Thus the delicate experiments of Magnus demonstrated that gases exist in the circulation, and that these gases, in variable proportions in the two kinds of blood, are composed of the constituent elements of the atmosphere. But whence do they come? In what condition are they found in the nourishing fluid? Is it in combination with other elements of this fluid, or in a state of solution? What is the office of each of them considered separately? This is just what we are about to investigate.*

I. OXYGEN.

The oxygen of the blood is found to exist in greater proportion than was believed by Magnus. The experiments illustrating the displacement of the gases of the blood by the oxide of carbon, recently made by Claude Bernard, clearly demonstrate this fact. This observer found, in effect, that 100 cubic centimetres of venous blood contain 8.42 cubic centimetres of oxygen, and 100 cubic centimetres of arterial blood contain 18.28 cubic centimetres of the same gas. According to the German school, the oxygen in arterial blood is less—from 15 to 16 per cent. in volume. (Setschenow.) In venous blood, as has been shown by Sczelkow, and by Claude Bernard in France,

* In this study of the gases of the blood I have borrowed from the unpublished work of my friend G. Sée, on the "Anæmias," several interesting accounts, particularly those which treat of the most recent German publications.

this quantity is extremely variable, according to the particular organs which furnish it, and their state of activity. Thus, the venous blood of the muscles, in a state of repose, contains, according to the German physiologist, 5.9 per cent. This oxygen of the blood is evidently derived from the atmosphere. So well are they known that it would be superfluous to recall here the experiments which have demonstrated this physiological fact.

But, having been introduced into the circulation, what becomes of this gas?

After MM. Dumas, Andral, and Gavarret, whose opinions are confirmed by M. Longet, and by nearly all modern physiologists, it would be difficult to conclude that it is a simple solution of oxygen in the blood, as has been assumed by some other authorities. "We know, in fact," says M. Longet,* "that the quantity in weight of a gas dissolved in water is in proportion to the external pressure." Applying this law to the present case, it follows that the blood of people who dwell in a locality where the atmospheric pressure is only three hundred and eighty millimetres, contains one-half as much oxygen as the blood of those who live at the seaboard, where the atmospheric pressure is seven hundred and sixty millimeters. Now, are we to admit that observers have not been impressed by the profound modifications which like variations do not fail to produce in the mode of existence of these two classes? On the other hand, if oxygen was simply dissolved in the blood, the external pressure remaining the same, the quantity of oxygen absorbed should increase exactly in proportion to the increased or decreased quantity of this gas contained in the atmosphere of the particular locality in which the experiment is conducted; whereas, on the contrary, the experiments of Lavoisier, confirmed by those of Regnault and Rieset, demonstrate† that the absorption of oxygen remains the same in an atmosphere which contains two or three times as much of this principle as is contained in common air.

Although the fact under discussion—the non-solution of the oxygen of the blood—is recognized by the generality of physiologists as true, we believe that the explanations invoked for its support are far from demonstrating it. The first of these, as admitted by Longet himself, may be contested, since a law applicable to gases dissolved in water cannot be applied to the

* Longet, Traitè de Physiologie, t. i, p. 582.
† Regnault et Rieset, Annales de Chimie et de Physique, 1849, 5th série.

solution of gases in a liquid of which the composition is so complex as that of the blood. In regard to the second explanation, based on the experiments of Lavoisier and confirmed by those of Regnault and Rieset, it is no more admissible than the first. These experiments, therefore, must have contained some source of error.

It certainly results, in fact, from our researches on the physiologic effects of inhalations of oxygen gas, more or less diluted with atmospheric air, that persons who breathe this gaseous mixture experience, after a few days, very sensible physiological effects, which will be studied further on; and that with animals having extensive ulcers, these sores, under the influence of the same inhalations, change appearance immediately and before the very eyes. Now, to what does this phenomenon, so easy to state, point to, if not to an increased absorption of one or more of the gases inhaled?

Since the interesting experiments of M. Dumas, all physiologists admit that the oxygen of the blood is chiefly found combined with the elements of this fluid. This combination serves, so to speak, but to fix a greater proportion of oxygen than is possible through a simple physical solution, and does not prevent that agent from exercising, later, a more profound action on the elements of the blood. The investigations of M. Dumas enable us to affirm that the *red corpuscles* are the elements in which this fixation of the oxygen of the air is effected throughout the circulatory system. It is by appropriating to themselves this gas that the red globules are arterialized, changing from deep violet to red, and are preserved in their integrity. Some modern chemists also admit that oxygen is more especially associated with the hæmatosin of the globules. "We know," says M. Longet, "the important rôle attributed to the principal ingredient of this coloring matter,—iron. It has been supposed that this metal exists in a state of protoxide in the venous blood, and of peroxide in arterial blood. The change that the blood undergoes in the lungs is that of superoxidation. The changes to which it is subjected in the general circulation, and which we are now to investigate, are, in effect, a reduction."

An experiment made by Claude Bernard demonstrates that oxygen is actually combined with the elements of the blood, and is not there merely in a state of solution. "In these experiments," says the eminent physiologist, "we undertook to deprive

the arterial blood of its oxygen, desiring to see whether the functional symptoms of asphyxiation would be the result. To determine this we had recourse to pyrogallic acid, a reagent which, in an alkaline medium, absorbs oxygen readily and completely. The blood being alkaline, it should follow that the injection of a solution of pyrogallic acid into the circulatory system would despoil the red globules of their oxygen. Now, nothing of the kind occurred. The injected pyrogallic acid was eliminated with the urine, without having undergone any alteration, and, hence, without having absorbed the oxygen from the red globules. From this failure to remove the oxygen of the red globules by pyrogallic acid, we must conclude that the oxygen of the blood is not free, that it does not exist in a state of simple mechanical solution, but is held in a state of combination."*

It is an established fact that the chemical combination of the oxygen with the globules is not so stable that it cannot be readily overcome. Thus, prolonged ebullition *in vacuo*, or treatment of the blood by means of another gas, as oxide of carbon, completely displaces all its oxygen.

M. Bernard, again, was the first to demonstrate this fact; but the oxide of carbon, according to this eminent authority, does still more. At the same time that it imparts to the blood a light-scarlet color, it renders it incapable of forming any new chemical combinations with oxygen. It is necessary, then, to assume that this oxide itself is in chemical combination, and that this combination is even more intimate than that of the oxygen itself. The quantity of oxide of carbon which is thus fixed is, moreover, equal to the volume of uncombined oxygen. These deductions of M. Bernard have since been verified by the physiologists Lothar Meyer and Hope. Another proof that oxygen is really fixed in the blood is this, that if certain substances are added, such as tartaric acid, the penetration of the globules by oxygen is such that it cannot be dissevered again by any other means. But that which still more positively proves this (that the oxygen of the blood is in close chemical combination) is that the oxygen is in that particular state called ozone, or active oxygen. All the recent investigations prove, in effect, that part of the oxygen existing in the red globules in a state of combination is in that modified condition or state called ozone, or active oxygen, and that the globules possess the same

* M. Claude Bernard, Leçons sur les Liquides de l'Organization, t. i, p. 357.

properties as the ozoniferous bodies discovered in the same connection,—salts of iron and platinum sponge, to wit:—

1. The globules of normal blood, or "whipped blood," and always of blood which has passed through membranes, act like these ozoniferous bodies. Placed in contact with the essential oil of turpentine, they possess the power to absorb from it ozone, and to impart it (ozone) to substances easily oxidized. With tincture of guaiacum a blue color results, and they decompose iodide of potassium in such a manner that the iodine liberated yields the characteristic blue color, with starch. (Schönbein *et al.*)

2. The serum and other constituents of the blood have no influence on these reagents. Only the red globules contain combined, and therefore active, oxygen. There are, then, no hæmatics aside from those which possess the power of ozonizing. All modern discoveries confirm the existence of this peculiar activity and its constant presence.*

3. Of the different elements of the globules, it is the hæmato-crystallin which appears to be the sole absorbent of oxygen and ozone; and in the hæmato-crystallin, already mentioned, it is particularly the hæmatin pure, since we can with impunity drive out of it the globulin, or can precipitate the latter by the aid of a current of carbonic acid passing through the diluted blood. After this process no further changes occur in the ozoniferous properties of the blood. Retarded blood, which has transuded through membrane, also preserves this peculiarity.

Thus, combined in the globules, oxygen traverses with them the left cavities of the heart, the principal arteries, their divisions and subdivisions, and reaches the capillaries. Here it abandons the globules, which re-assume their violet tint, and the result of this separation is to produce transformations, combinations, complete or incomplete—combinations which lend themselves at once to the needs of nutrition and to the necessity for eliminating such substances as are no longer useful or available for the maintenance of life. Of products destined to be expelled from the economy there are two kinds. One escapes through the respiratory surfaces, and contains carbonic acid, nitrogen, and also aqueous vapor, with which we will not occupy ourselves at present. The other, which we will also ignore, is

* This fact readily and satisfactorily accounts for the difference in activity between freshly prepared or nascent oxygen and that which may be termed passive or stale oxygen. (See "Varying Conditions," etc.).—Trans.

eliminated by the kidneys, bowels, and other avenues of excretion, and contains besides nitrogen, carbonic acid, and traces of free oxygen, some nitrogen, carbon, hydrogen, and oxygen, united in less simple combinations and associated in such a manner as to constitute the immediate organic principles of the excrementitious mass, to use the expression of M. Dumas.

In summing up the foregoing considerations, we may appropriately cite the conclusions of modern physiologists, which have been formulated by M. Germain Sée in his work on Anæmia:—

"(*a*) The red globules are the vehicles of combined oxygen and of ozone.

"(*b*) Their diminution necessitates the following consequences:—

"1. A functional alteration is produced in the organs which, like the muscles, utilize the most oxygen for the regular accomplishment of their functions.

"2. Sensibility is blunted.

"3. The nervous centres are perturbed because they lack their normal stimulant—oxygen.

"4. The temperature is lowered, hence combustion is less active.

"5. The respiratory function is very much disturbed, the necessity for breathing is more pressing, and the gaseous changes are rendered more imperfect.

"6. The innervation of the heart is interfered with."

II. CARBONIC ACID.

The details already submitted sufficiently explain the origin of the carbonic acid of the venous blood. This gas results from the combination, or, more accurately speaking, from the combustion of carbon in the general capillaries in contact with the free oxygen derived from the red globules. In most of the works on physiology, Laviosier is made to say that the combustion of the constituents of the blood is effected in the lungs, and not in the capillaries. That sage never admitted either of these opinions to the exclusion of the other. According to him, carbonic acid is produced either in the lungs or in the blood, and he does not adopt the special doctrine attributed to him by so many writers —that is to say, that combustion of oxidizable material in the blood is accomplished wholly by contact with the oxygen of the air in the lungs. To verify the assertion we here make, it is

sufficient to cite his memoir of 1789. Let us then pay a merited tribute of eulogium to the immortal labors of that illustrious man, for they were the initiative of the important discoveries which have since been made on this subject.

Spallanzani was the first who, in an essay on respiration, demonstrated in a precise manner, by experiments on snails, that carbonic acid is formed in the general capillaries, and that it is carried, ready combined, by the venous blood to the pulmonary surfaces, on which the office of exhaling it devolves at the same time that it absorbs oxygen. Then followed the confirmatory experiments of W. Edwards, of Collard, of Martigny, of Müller, and of Bergemann, the discovery of the gases of the blood by Magnus, and, finally, the experiments of Bischoff, from which it follows that frogs in which the lungs have been ligated, and their action thus suspended, continue to exhale carbonic acid by the skin—carbonic acid which evidently cannot come from any other source than the oxygen accumulated in the blood by means of previous respiration.

After the evidences furnished by these observers, it is incontestable that carbonic acid is evolved in the substance of our tissues. M. Bernard (*op. cit.*, t. i, p. 339), pursuing this interesting subject, by no means admits the transformation of oxygen into carbonic acid as a result of the contact of this gas with the carbon of our tissues. According to him, this transformation occurs in the blood itself, and, although it is true that carbonic acid is exhaled from the pulmonary surfaces, the above fact is now fully established. But in its passage through the venous circulatory apparatus, in what condition is it found in the blood? According to the generality of physiologists, it is combined with other elements of the circulating fluid, and not in a state of mechanical solution, as Magnus believed it to be. We have already asserted that oxygen in the lungs is combined with the iron of the red globules to form peroxide of iron, and that this peroxide, in consequence of its instability, and by the assimilation of the blood in the capillaries of our tissues, is reduced to a protoxide in the venous blood. It is admitted that the carbonic acid of this last blood is combined with the protoxide, and forms with it a more stable compound, which duplicates itself on contact with atmospheric air in the lung. According to Setschenow, a fraction of the gas is in a chemical state, but the greater part is in suspension; and the quantity of gas thus

dissolved, or in solution, much exceeds the quantity of oxygen absorbed.

The reason, according to that physiologist, is quite simple. Water absorbs infinitely more carbonic acid than oxygen, and the serum behaves in a marked degree like water; that is to say, it simply dissolves the gas.

Setschenow admits, again, that, since the serum acts relatively to the carbonic acid as does the entire blood, it results that the chemic action of the carbonic acid must be looked for in the globules, as occurs in case of oxygen, and it must also take place simultaneously with the solution of the dissolved portion in the serum itself. Now, that part of the serum which appropriates this fixed portion of the carbonic acid is, as has been shown by M. Fernet,* phosphate of soda. Sundry attempts have been made by Lothar Meyer with an aqueous solution of carbonate of soda, which, in fact, chemically attracts 1.087 parts of carbonic acid, in the condition of a bicarbonate, and 0.818 in the form of dissolved gas; but the blood must not be compared to a solution of bicarbonate of soda, since the quantity of this salt contained in the blood, estimated according to the proportion of the combined carbonic acid, is too inconsiderable to retain, under the form of a bicarbonate, all the carbonic acid that the blood can absorb, artificially, in an atmosphere of pure carbonic acid gas. On the other hand, arterial blood, which should comport itself like venous blood, does not contain free carbonic acid gas, or barely five or six volumes per hundred,—a quantity which corresponds exactly with that of the chemical (combined) gas. Thus, in the circulating blood there are conditions which prevent the permanent formation of bicarbonate of soda. Another element must then contribute to retain the gas. The phosphate of soda performs this office. (Fernet.) We close this paragraph by referring briefly to the relation which exists between the oxygen absorbed during respiration and the quantity exhaled in the form of carbonic acid gas.

Lavoisier was the first who studied this relation. He observed that carbonic acid exhaled during respiration does not represent all the oxygen inspired. In a work prepared in common with La Place,† he announced that "in a given time a quantity of caloric is disengaged in excess of that which ought to result

* Du Rôle des Éléments du Sang dans l'Absorption. Paris, 1858.
† Mém. de l'Acad. Sci., 1780, p. 355.

from the carbonic acid gas evolved by respiration during the same interval."

Later, in 1785,* he asserted "that quite probably respiration does not reach the point of the combustion of carbon, yet does occasion combustion of a part of the hydrogen contained in the blood." In fact, this idea is very clearly formulated in his memoir of 1789.† From that time forward we have had an experimental fact as a base. This illustrious physiologist effectually maintained that the carbonic acid exhaled by man or animals never represents the totality of the oxygen absorbed.

Later on, Allen and Pepys,‡ experimenting on man, were led to infer that the volume of carbonic acid gas exhaled is equal to the volume of oxygen consumed. According to W. Edwards § the relation found to exist between the oxygen of the carbonic acid expired and the total oxygen absorbed varies from 66 to 100 per cent. According to Despretz,‖ the relation between the volume of carbonic acid exhaled and that of total oxygen absorbed varies from 0.62 to 0.78. According to Dulong,¶ the total volume of oxygen consumed is quite as much in excess of the carbonic acid exhaled. There is, then, a part played by oxygen other than that of forming carbonic acid. The excess of volume of oxygen absorbed over that of carbonic acid exhaled represents, approximately, one-tenth of the latter, rising to one-fifth in rabbits, guinea-pigs, and pigeons. On the contrary, in dogs, cats, and kestrels this proportion is never less than one-fourth, nearly always equals one-third, and sometimes reaches one-half.

Again, MM. Regnault and Rieset** diligently endeavored to estimate with accuracy the relation in question. They observed that the carbonic acid exhaled in a given time represents less oxygen than the animal imbibes (or inspires) during the same time. Lavoisier had already announced as a thoroughly demonstrated fact, and it is therefore allowable to admit, with him, that since the whole of the oxygen is not utilized in the combustion of carbon, a part of it may combine with hydrogen to form water. This theory is now admitted by all. It is the doctrine taught by the classical works on physiology. MM. Regnault and Rieset have also maintained that in animals of the same species, surrounded by the usual conditions of their

* Reçueil de la Société de Médecin.

† Mém. de l'Acad., etc., 1789, p. 570.

‡ Philosoph. Trans., 1808.

§ De l'Influence des Agents Physiques sur la Vie. Paris, 1824.

‖ Annal. de Chimie et de Phys., 2d série, t. i.

¶ Annal. de Chimie et de Phys. 3d série.

** *Op. cit.*

existence, the relation between the oxygen represented by the carbonic acid produced and all the oxygen consumed is but slightly variable. In the dog this relation is 0.743 to 0.750; in the rabbit, from 0.920 to less, as a mean, etc.

III. NITROGEN.

The nitrogen of the blood, like the oxygen and carbonic acid, was first demonstrated in an irrefutable manner by the experiments of Magnus, who considered this element as merely dissolved in the nourishing fluid. This opinion is still generally adopted, and nitrogen, following the apt language of M. Longet, "is evolved there (in the blood) as in running waters which freely communicate with the surrounding atmosphere." This learned physiologist also remarks that it is not at all a matter of inquiry, as has been the case of the two preceding gases, whether nitrogen exists specially dissolved in the serum or in the globules. According to MM. Fernet and Setschenow, a portion of this gas also appears to be chemically combined, as in case of oxygen and carbonic acid. It should certainly exist in the globules. This is a point which demands further study. As to its origin, it has been the subject of numerous discussions, as have all the questions relating to hæmatology, and demands, so to speak, absolutely mathematical precision in chemical experiments.

We can divide the opinions which scientists entertain on this subject into two groups.

Lavoisier maintained that nitrogen did not change sensibly during respiration; that is to say, there is neither absorption nor exhalation of this gas.* In their work, as we have stated, Allen and Pepys† concluded that the quantity of carbonic acid exhaled is, volume for volume, equal to the quantity of oxygen consumed, and that respiration does not appear to disengage hydrogen or any other gas. They admit that there is neither absorption nor exhalation of nitrogen. Humphry Davy, Pfaff, and Henderson alike admit that respiration produces no change in the proportions of the medium in which the animal under experiment is placed.

But here comes a series of other observers before whom the phenomena of respiration do not pass so simply.

W. Edwards‡ admits that in certain cases the nitrogen of the air has not incurred any perceptible change (during respira.

* Mém. de l'Acad. Paris, 1789. † *Op. cit.* ‡ *Op. cit.*

tion), and we may agree with him that there is no exhalation of nitrogen apparent. The disagreements on this point may be attributed to errors of analysis. But in a large number of other experiments made during the spring and summer the excess of nitrogen found in the atmosphere after it has been respired is such that the exhalation of this gas cannot be denied. This excess greatly surpasses the volume of the lungs. It forms a considerable part of that of the (entire) animal. It rises in some instances to one-fifth or even to one-fourth of the total quantity of oxygen consumed. Experiments made with small birds during the winter have given diametrically opposite results. The diminution of nitrogen was as marked as was its excess in the experiments made in summer. Nevertheless, no one has ever observed any absorption of nitrogen, whether in summer or winter, in very young mammifers, such as little guinea-pigs.

Accepting these conclusions, M. Edwards thinks that when an animal breathes in atmospheric air, the functions of absorption and release of nitrogen are simultaneous; that, on the one hand, it absorbs nitrogen, and, on the other hand, exhales it. Of the relation between the quantities of nitrogen absorbed and that exhaled three different results may occur, according to the constitution of the individuals (experimented on) and the surroundings in which they are placed. Whenever exhalation exceeds absorption we observe only the evidences of exhalation. When absorption predominates we note only the evidences of absorption. Finally, whenever these two processes occur in the same proportions we do not note the effects (evidences) of either, and the nitrogen expired exactly equals the nitrogen inspired.

M. Edwards interprets the phenomena of respiration in the following manner:—

Oxygen which disappears during respiration in the medium of atmospheric air is entirely absorbed. It is at once, wholly or in part, carried into the circulation. It is replaced by a variable but considerable quantity of exhaled carbonic acid (the proportions have been already stated), which is derived wholly or partly from that contained in the mass of the blood. An animal breathing atmospheric air also absorbs nitrogen. Absorbed nitrogen is carried wholly or partly into the mass of the blood. Nitrogen absorbed is replaced by a quantity, approximately equivalent, of exhaled nitrogen which is derived wholly or partly from the blood.

Despretz* admits that there is an exhalation of nitrogen in the respiration of carnivorous and frugivorous mammifers, and in that of birds. The quantity is greater in frugivora than in carnivora.

In his experiments this observer has found that the relation between the volume of nitrogen exhaled and of oxygen consumed varies from 0.10 to 0.33.

Dulong † admits that in the act of respiration the volume of nitrogen released is less than the oxygen absorbed in case of the carnivora, and sometimes but rarely exceeds it in the frugivora. In Dulong's experiments, the release of nitrogen compared to the volume of oxygen consumed varied from nothing to 0.28. The discrepancy which appears in the results of Dulong's experiments and those of Despretz consists in this, that in the first the elimination of nitrogen was less than in the second. But, as set forth by MM. Regnault and Rieset, it is easy to determine by a simple process of reasoning, that the enormous exhalation of nitrogen which should take place in the respiration of animals is absolutely impossible. In fact, the quantity of nitrogen exhaled during twenty-four hours by the respiration of an animal should not only quite exceed the quantity received by the animal in the food ingested during the same time; but, even excluding the considerable quantity evacuated in the secretions, the animal should release in a few days more nitrogen than is contained in its entire body.

M. Marchand,‡ in a series of experiments on Indian pigs, undertook to determine whether, in the act of respiration, nitrogen was released or absorbed. He noticed that in all his experiments nitrogen was exhaled, but that the proportion of it was very minute. Thus, in ten experiments on Indian pigs, he found that, indicating the volume of carbonic acid by 100, the volume of exhaled nitrogen was but 0.94. Three experiments, made on a pigeon, gave as a result 0.85 of exhaled nitrogen.

M. Boussingault, experimenting on a cow, a horse, and a turtle-dove, found that in every instance the volume of nitrogen exhaled formed but a small fraction of the carbonic acid released (during the same time).

M. Barral, experimenting on man, arrived at the same

* Annales de Chimie et de Phys., 2d série, t. xxvii.
† Annales de Chimie et de Phys., 3d série, t. l.
‡ Journal für Practische Chemie, t. xliv, p. 1.

result.* He noted a release of nitrogen amounting to about 1 per cent. of the volume of evolved carbonic acid.

Finally, MM. Regnault and Rieset, in their memoir already so often cited, arrived at the following conclusions as regards warm-blooded animals:—

1. When (warm-blooded) animals are subjected to their usual alimentary regimen they constantly exhale nitrogen, but in very small quantity, never rising to 2 per cent. of the weight of the total oxygen consumed, and in most instances it is less than 1 per cent.

2. Animals kept without food often absorb nitrogen, the proportion absorbed varying between the same limits as that of nitrogen exhaled by animals when kept under their usual regimen. The absorption of nitrogen is almost constant in birds, but rarely in mammals kept without food.

3. When an animal, after having been kept for some days without food, is then placed upon a dietary quite different from its usual food, it often absorbs an increment of nitrogen during a certain period, probably until it adapts itself to the new regimen. It reverts then to its normal condition and gives off nitrogen. This fact has been fully established in case of hens, which, after having been kept several days without food, were changed from a diet of grain to one consisting of flesh only.

4. When an animal is suffering in consequence of having been placed on an unnatural or unusual diet, or perhaps from other causes, it still absorbs nitrogen.

These conclusions are quite generally adopted by physiologists. It is now admitted that in normal conditions—that is to say, outside of pathologic influences and a state of inanition—the animal does not fix (absorb) any portion of the nitrogen of the air, and that, hence, the external nitrogen does not enter into the composition of the blood. On the other hand, if we consider, as stated by M. Longet, that the mean quantity of nitrogen exhaled remains stationary in animals, however well nourished, which live in an atmosphere of pure oxygen, or, better still, in one composed of oxygen and hydrogen, we shall be forced to the conclusion that the nitrogen of the blood must be derived from within,—that is to say, from a process dependent upon the organism itself.

* Annales de Chimie et de Phys., 3d série, t. xxv.

IV. RELATION OF THE GASES TO EACH OTHER.

We conclude this study of that which relates to the gases of the blood in a physiologic state by a brief statement concerning the reciprocal influence exerted by these gases on each other and on the salts of the nourishing fluid.

According to M. Longet,* chloride of sodium, in conjunction with albumen, constantly introduced into the blood by alimentary absorption, is presumed to co-operate with it (the albumen) in preventing the disintegration of the red globules, assisting, on the contrary, in the decomposition of certain organic elements and their metamorphosis in the presence of oxygen.

The phosphate of lime is, as we know, insoluble in water. Nevertheless its presence in the blood is as constant as that of the last-mentioned salt. It is found there in a liquid state, now free and now combined with albuminous substances. Although the alkaline bicarbonates and the chloride of sodium assist in dissolving a portion of it, it is by the aid of carbonic acid that it becomes sensibly soluble. The phosphate of soda, as we have already seen, facilitates the absorption of carbonic acid by the venous blood, and its subsequent elimination from the organism. In fact, carbonate of soda, of which the quantity in the blood much exceeds that of the phosphate, is said to be easily decomposed in the blood itself, under the influence of lactic acid, which has its origin in the metamorphosis of feculent or nitrogenous alimentary matters. Thence follow the formation of lactate of soda and the liberation of carbonic acid.

This completes a summary of the principal details associated with a study of the gases of the blood. A much more complete statement could have been made, and we might discuss more at length the controverted points of this interesting subject; but a study *in extenso*, besides necessitating the verification of numberless recent experiments, as also of many difficult ones which have been made by physiologists through nearly a century, would have drawn us far from the subject aimed at in this chapter,—that of preparing the reader for a ready understanding of the various questions which will be treated in the course of this work.

* Traitè de Physiol., t. i, p. 492.

CHAPTER II.

OXYGEN.

I. MEDICAL HISTORY OF OXYGEN.

1. PRIESTLEY AND HIS PREDECESSORS.—It will not be paradoxical, having attempted the subject, to endeavor to go back to the historic origin of oxygen in a quite remote epoch. According to Burdach,* ever since the time of Democritus, it has been conceded that the atmosphere supplies to the blood some principle necessary to life, and it was designated by the name of *vital spirit*, or *πνευμα*. In view of an opinion so nearly accurate it would seem that it was but a step farther to arrive at the discovery of vital air and the inauguration of pneumatic medicine.†

It took science more than two thousand years to cover this little step. We might go back still farther and dilate on the symbolic cult which, a century and a half before Democritus, the philosophers of the Empiric School, and particularly Anaximenes, had dedicated to the atmosphere, which they made the primal or supreme element, the essential life, the soul, the very Deity. But mere erudition would here be put out of place, and, besides, would be of but secondary interest. We have considered, however, that it would be interesting to look up the predecessors of Priestley in the discovery of the properties of oxygen; and here, it will be evident, we enter at once into the history of the subject which engages us.

As has been frequently remarked, there are two methods of discovering a planet: in the study, aided only by calculation; or above, in the observatory, with the aid of an astronomer's glass. And more than once the spiritual eye has seen far in advance of the physical vision, and with as much accuracy. It

* Physiol., chapter ix, p. 521.

† We have often, in the course of this work, used the term *pneumatic medicine*, but always as a synonym of the application of the gases to therapeutics. It would, perhaps, have been more accurate to have reserved that nomenclature to designate the school or medical doctrine founded by the Athenians. But, believing that confusion is impossible in connection with such a subject, we decided that we could avail ourselves of this expression indifferently, without fear of being misunderstood.

has been the same in the case of oxygen, the existence of which was (practically) announced by induction long before experiments had demonstrated it. It is customary to trace the history of the discovery of oxygen back to Mayow. But for two hundred years science had been equally advanced in a speculative point of view. We find, in fact, in a treatise, entirely forgotten to-day and scarcely better known at the time it was published,* the following statement, which comprehends the germ of the chemical theory of respiration and combustion:—

"Fire incessantly destroys the air which nourishes it; it would create a void if other air did not rush to replace it.

"Whenever air is not in a fit condition to burn (*recevoir la flamme*) neither fire nor any terrestrial or aerial animal can survive therein."†

The foregoing was written by Leonardo da Vinci, who lived in the second half of the fifteenth century, and who cultivated with ardor the physical and natural sciences. Unfortunately for posterity, the contemporaries of this great artist and their immediate successors saw in Leonardo only the author of "Joconde," of "La Vierge aux Rochers," and other masterpieces (in art). This was sufficient, it must be admitted, for their admiration and his glory; but the man as a scientist was misunderstood and forgotten. Perhaps, also, his ideas were too bold for the times. Mayow, however, who came two centuries later, has met with the same scientific fate. These were, in some degree, brilliant meteors, which at different intervals traversed the sombre sky of science, illuminating it for an instant; then all relapsed into the obscurity of ignorance and error. To him who reviews the history of this long infancy of modern science these are as beacons which aid in following the sometimes difficult and painful, and sometimes triumphant march of the human soul in the search for truth.

About 1668, Mayow conceded that "a nitro-aerial spirit is the vital principle of the air, the sustainer of combustion and respiration; that it constitutes but one portion of the mass of the air, and that animals, by means of their respiration, consume it the same as does a burning body. Finally, that the igno-aerial particles absorbed in respiration are designed to change venous into arterial blood, and that this absorption is the source

* Traitè de l'Air et de la Flamme, Œuvres Scientifiques de Leonardo da Vinci.
† Venturi, Essai sur la Vie et les Ouvrages de Leonardo da Vinci, 1797.

of the heat which is developed in the human body." He recognized also that "the air removes from the blood some vapors or effluvia which are thus expelled from the organism." He developed these ideas and confirmed them by very exact experiments, which he recounted in his work on "Le Sel de Nitre et l'Espirito Nitro-aerian," published in Oxford, in 1674.

We mention, in passing, N. Le Fevre, Robert Boyle, and Drebbel, who put forth ideas analogous to those of Mayow; afterward the chemist Hales, whose "Statique des Vegetaux"* contains some very ingenious observations which contributed to hasten the hour of the important discovery to which we have at last arrived.

It was on the 1st of August, 1774, that oxygen was for the first time isolated. The occurrence is remarkable enough for us to recite here some circumstantial details concerning the discovery of a gas which has been called upon to play so important a rôle in chemistry and in medicine.

Let Priestley speak:—

"The 1st of August, 1774, I attempted to derive air from mercury, calcined *per se*, and I at once discovered that by means of a powerful lens I could drive the air (gas) out of it very promptly. Having collected of this air about three or four times the volume of our material, I admitted it into water, and I found that it was not absorbed; but what surprised me more than I can express was that a candle burned in this air with a flame of remarkable intensity." †

Behold, at last, oxygen discovered! ‡

Yet it was only after having proved the identity of the gas obtained by decomposing red lead by heat or electricity, with the gas of calcined mercury, that Priestley positively ascertained that he had isolated vital air, or *dephlogisticated air*, as he called it. No, indeed! He had discovered only chemic oxygen—the gas which is derived from oxides, and which accelerates combustion so powerfully. Physiological and medical oxygen was yet to be discovered. But more: Priestley himself, after the results he had obtained, did not in the least doubt, even from the outset.

* London, 1733.

† Priestley, Exper. et Observ. sur l'Air, etc., translated by Gibelin, chapter ii, p. 41.

‡ In a purely chemical point of view, it is necessary to inquire to what extent Boyer, Scheele, and Lavoisier took part, each in turn, in this important discovery. But, as we are not here discussing the *medical history* of oxygen, we believe it just to accord all the honor of the discovery to him who first isolated it and experimented (with it) physiologically for the first time.

He believed that he had disengaged from calcined mercury only an air having the greatest similarity to common air, and being substantially the same thing. Not until the 8th of March, 1775, after having seen a mouse placed in a receiver, filled with this air, survive in it twice as long as in ordinary air, did he realize the superlative salubrity of this fluid.*

Convinced from that moment that he had discovered the vital principle of the atmosphere, Priestley sought to make useful applications of it. He proposed to use it to purify the air of apartments and of halls where crowds were found confined. He also thought he would be able to utilize it as a therapeutic agent. "The increased force and brilliancy which the flame of a candle acquires in this air leads us to conjecture that it would prove peculiarly salutary to the lungs, in certain cases of disease in which common air does not prove sufficient to evacuate (eliminate) with due promptness the putrid, phlogistic effluvia. But perhaps we should infer also from these experiments that pure, dephlogisticated air, however useful it may prove as a remedy, we should not find it equally desirable in an ordinary state of health; for, just as a candle is consumed much more rapidly in dephlogisticated air than in common air, we might also *live*, so to speak, *too rapidly*, and the vital force would be too quickly spent in this pure species of air. Doubtless a moralist can assure us that the air which is accorded us by nature is as good as we deserve."

This argument, deduced from final causes, seems tinged with a certain irony, coming from the pen of a bold thinker whose scarcely orthodox philosophic opinions forced him to quit his country. It is true that these same opinions, together with his high repute as a chemist, secured him a reception at Paris which should have consoled him a little as to his exile.

But we return to our interesting quotation :—

"My readers will not be astonished that, after having established the superior salubrity of the dephlogisticated air, by the life of mice and by other proofs which I have reported here below, I had the curiosity to try it myself. I satisfied my curiosity by breathing it with a glass siphon, and by this means I reduced a large jar of it to the condition of common air. The sensation which my lungs experienced was not different from that produced by common air. But it seemed to me that my

* See the curious history of this second discovery, *op. cit.*, p. 49 *et seq.*

chest was singularly cleared and at ease for some time. Who can assure us that this air will not at some future time become a very fashionable object of luxury? Hitherto only two mice and myself have had the privilege of breathing it."*

In writing these lines, Priestley very faintly foresaw the strange destiny which oxygen was to have in the medical world.

As we are not giving here the chemical history of oxygen, nor even the history of respiration, we will not stop to mention all the works, far and near, which relate to the gas we are studying. We will dwell only on those which treat of the therapeutic action of vital air.

2. From Priestley to Fourcroy.—Priestley's discovery gave a considerable impulse to the labors of his contemporaries in that very interesting department of chemistry applicable to animal physics. Thus, a great scientific movement was inaugurated in that field which yet engaged the majority of the scientists who illustrated the last half of the eighteenth century. And when we recur to the thought of that period, we comprehend how the minds of that time were continually captivated with the idea of being able, after so many efforts, to easily manipulate and to employ at will this pure air of which they had so long had glimpses, without being able to isolate it. Hence, the chemical and physiological experiments concerning respiration have never been quite so numerous as during that time. It is sufficient to cite the names of Spallanzani, of Fontana, of Ingen-Housz, of Kirwann, of Barthollet, of Lavoisier, etc., to show that the most illustrious scientists of the time had the courage to advance science, to some extent, in this direction. Thereby physiology gained certainly very much, but medicine realized little of value.

From the day that, thanks to Lavoisier, the elementary composition of (atmospheric) air has been perfectly well known, it has been desired to study the office of each of its constituents in the process of respiration, and the greater part of the researches made have been directed toward this end. Each observer has been pleased to repeat the experiments of Priestley, and to relate, after him, that animals survive much longer in vital air than in common air. Fontana,† Spallanzani,‡ Count

* *Loc. cit.*, p. 125.

† Researches on Nitrous Air and Dephlogisticated Air, Priestley's Works, vol. v.

‡ Sennebier and Spallanzani, Reports on Air and Organized Beings.

de Morrozzo,* and Ingen-Housz† have published numerous researches on this subject, and we will attempt to show how much originality belongs to each one in these investigations.

According to Fontana, the mean life of mice, in a given quantity of common air, is thirty minutes, while in an equal volume of pure (vital) air it is one hundred and forty minutes, young specimens surviving for a shorter period than old ones.

Spallanzani, who made numerous experiments on respiration, throughout the whole animal chain, sought especially to determine the influence of organization peculiar to each animal on the quantity of oxygen necessary to it. It is thus that in comparing, in this connection, caterpillars, their chrysalides and their butterflies, Spallanzani noted that caterpillars absorb a moderate quantity, chrysalides very little, and butterflies very much of it. Sennebier, who added somewhat to the experiments of his friend, seemed much surprised and even confused by this variation, of which he did not, at first, know how to fathom the cause.

"However," said he, "it would seem that the quantity of oxygen gas absorbed is proportionate to the relative degree of motion displayed by the animal in its three states,"‡ and he concluded that this difference of absorption had its cause in the variety of organization of the muscular system. Let us note, *en passant*, that Beddoes was by other methods enabled to localize the special action of oxygen in the muscular system.

Count de Morrozzo, who experimented principally upon birds, pointed out that these animals exhibit in oxygen more sprightliness, more vivacity, and when permitted to die in this gas the end of their lives is not accompanied by convulsions like those observed in birds that die in a limited quantity of common air. Furthermore, the heart retains its irritability several hours after death—a fact established with the utmost care by La Metherie.§ The latter, better known as a philosopher than by his scientific labors, also assured himself that this phenomenon is exhibited for the longest possible time when death takes place in oxygen.

*Sur la Respiration anim, dans le Gaz. Dephlogis., Journal de Physique, chapter xxv, 1784.

†Sur l'Air Dephlogis., etc., Mém. de la Soc. de Phil. Exper. de Batavia, chapter vi, 1782; Compte Rendu dans le Jour. de Médecine, chapter lxi, p. 188.

‡*Op. cit.*, chapter ii.

§La Metherie, Essai Analytic sur l'Air Pur., etc., 2d ed., chapter ii, p. 22.

We do not lay stress upon these studies, however interesting they may be. We merely mention them, since we again repeat that we are not attempting the history of respiration, but solely the *medical* history of oxygen.

Ingen-Housz tried the medical properties of oxygen on himself. After having inhaled a certain quantity he felt more sprightly, more robust, and had increased appetite; also, his sleep was sweeter and more refreshing than usual. This appears to be a transition to the purely medical rôle of oxygen. We will therefore now pass to a series of studies which aimed to determine the physiologic and therapeutic action of oxygen on the organism.

It is quite curious to note this fact, that within a period of two years three theories have been advanced concerning the most impressive of those experiments, which we have just rapidly enumerated, without having been scarcely noticed. Two were published in Edinburgh,* but we have succeeded in finding only the advertisements of it in the English journals of the day. The other, published at Montpellier,† was considered so interesting that a full translation of it was given by the *Journal de Médecine*,‡ and it is evident from the too brief *résumé* of this (latter) article that it was worthy of commendation; the indications and contra-indications for the employment of oxygen in medicine are described quite too briefly, but with a very remarkable clearness considering the time—1785:—

"It is to this air that the blood owes its vitality; it is the sustainer of animal heat; it agrees with those asthmatics whose condition is not caused by excess of irritability;§ it is useful in bilious, putrid, and malignant fevers; in the plague; in consumption, provided there is neither (active) inflammation nor excessive sensitiveness. We can mix it with the fumigations employed in diseases of the chest, and may use it to purify air which needs to be renewed. It is the grand resource in restoring to life asphyxiated persons; finally, it will prolong the last

* Jonathan Stokes, Concerning Dephlogisticated Air: Edinburgh, 1782. Henry Burton, Concerning the Uses and Effects of Pure Air on the Human Body: Edinburgh, 1788.

† Positiones Chymico Médicæ de Aere Vitali sur Dephlogisticato, Tanquam novo sanitas præsidio. Auctore, Alex. Poulle. Monspel, 1784.

‡ Journal de Médecine, chapter lxiii. p. 247, 1785.

§ "Excess of irritability" is scarcely a rational guide at this day, as regards the indications for using oxygen in asthma. *Pure* oxygen, in reasonable quantity, does not tend to increase irritability Due allowance must here be made for the impurities then unavoidable in the gases used.—Trans.

moments of the aged by rekindling in them the fire of life about to be extinguished."

We have stated that as soon as oxygen had been isolated, physiologic experiments were multiplied with a view to determine to just what extent it is necessary to the maintenance of life, and what quantity a man daily consumes. The learned societies began to be interested in this subject, and in 1784 or 1785 the Royal Society* of Medicine put up for competition the question of the utility of eudiometry, and the service it might render to medical art.

The prize essay is the most interesting and conscientious paper of which we have any knowledge. Indeed, Jurine, of Geneva, who was its author, devoted himself to extensive researches on respiration, and especially to an analysis of the air contained in the lungs in a state of health, and in some diseases.

The conclusions at which Jurine arrived, although he did not devote special study to the therapeutic action of oxygen, deserve to be mentioned, since they appear to us calculated to elucidate to some extent the part performed by this gas in the intimate phenomena of life:—

"The feverish state increases the production of carbonic acid gas.

"During the shivering stage of a fever I have determined that a bed contains three per cent. of carbonic acid, and during the stage of perspiration seven per cent.

"After a venesection to the extent of five hundred grammes, practiced on an individual thirty-six years of age, the quantity of carbonic acid was reduced one-fourth—eight to six per cent.

"The knowledge which I have acquired," says he, elsewhere, "by the repetition of so many experiments made upon the air of the lungs in persons who were in health, led me to entertain the hope that I should find, by analysis of the air emanating from the chest in this or that malady, particular modifications which would prove characteristic of the disease, and would serve to indicate the necessity for employing in some cases vital air, pure or diluted, or chalky (carbonic?) acid, as an essential and very useful remedy, but I have been deceived in this hope."†

* This title is perhaps not the exact text, but it is the exact sense, *vide* Mémoires de la Société de Médecine, 1789, chapter x.

† *Loc. cit.*, p. 50.

However, some pages further on we find the following observation: "which," he says, "becomes interesting on account of the prolonged use made of vital air in a disease of the chest, and which was communicated to me by one of my friends, a professor of physics." He himself made the experiment in the case of Miss M., aged thirty-one:—

"This young lady, according to the report of her physician, was decidedly consumptive. He had exhausted all the resources of his art to cure or relieve her; the disease made daily progress, when she decided to make trial of vital air. She began on the 24th of April. A short time afterward she observed that her strength, which had been very much reduced, returned to her in such a degree that at the end of the month of May she was sufficiently strong to be able to ride on horseback quite a long time. This young woman inhaled each day a receiver full of it (oxygen), which held about seven hundred ounces of water. This operation she completed at two several times, respiring at first, while compressing the nose, about ten minutes, or until the ease she at first experienced was changed into difficulty. The cock was then turned off and the bell-glass was allowed to rest on the water nearly twelve hours, after which she breathed the air for about five minutes. At the end of this time the wax-taper did not burn better (under the receiver) than in atmospheric air, and sometimes not so well. The disease continued during six months' trial of the remedy; she left it off in October and died the following winter. My friend was persuaded that had she been willing to submit herself to a *régime* in the least reasonable she would have lived a much longer time. But she spoiled all the good which the remedy could effect by living in the most fashionable circles, by constantly dining out, eating heartily, without selection or discrimination; in fact, by living a life which would have been hurtful to a person in good health."

This quite remarkable case, added to one which Cailliens had published in 1783, in the *Gazette de Santè*,* another which Chaussier had presented in 1785 to the Academy of Dijon, and to many others which had not been published, but of which the results had been reported from mouth to mouth, after the numerous physiologic experiments as to the exceptional healthfulness of vital air,—all ended by arousing not only the medical

* *Loc. cit.*, p. 50.

profession, but the entire public. Thus, the government only yielded to the general wish when it demanded from the Academy of Sciences its opinion of the expediency of a remedy which was said to be so efficacious in the treatment of pulmonary consumption.

Fourcroy was commissioned to pronounce upon the therapeutic value of oxygen. But as this chemist has played a conspicuous part in the history of this gas, we will, before quoting his report, mention the results of some clinical experiments attempted about the same time by the chemist Chaptal. Although the letter in which the results are found recorded may have been written subsequent to the date of the publication of Fourcroy's account we will speak of it here, because it was written under the inspiration of the same ideas which gave occasion for the investigations of the Academy of Sciences. The following is therefore what Chaptal wrote from Montpellier on September 1, 1789, to his friend Berthollet*:—

Phthisis in the Last Stage.—"The effect of it (oxygen gas) was so prompt that in the space of three weeks the patient was able to leave his bed, and gained sufficient strength to take long walks. Six months later he relapsed, and not having any longer the facilities for respiring this (vital) air he died. This young man ardently desired the employment of the gas; he was consciously relieved when he respired it, experiencing a sensation of warmth which spread itself from the chest to all the extremities, and it seemed to enliven and invigorate the failing machine.

"I have had opportunity to observe exactly similar results in case of another young man, aged 22 years. The effects of the remedy were not favorable;† but it inspired him with the same good spirits, and from this point of view, alone, this remedy is valuable, for in hopeless cases it spreads flowers about the portals of the tomb, and masks the horror of the appalling transition!

"The effects of this gas on the lungs caused me to believe that it would be beneficial in cases where the viscera are engorged with mucous fluids, and at all times when it is necessary to endeavor to incite and revive a languishing organ. Conse-

* Annal. de Chim. et de Phys., 1st série (one of four volumes).

† This would seem ambiguous and inconsistent if we did not realize how crude were his processes and how impure his gas.—Trans.

quently, I have caused an asthmatic to inhale it, with the result that he was wonderfully relieved.

"I believe that it will be useful in moist asthma only, and that it may be hurtful in dry asthma.

"I ought to observe to those who may be induced to try the use of oxygen gas that it is very dangerous to employ that which is derived from oxides of mercury. I have invariably noted that the use of this gas produced salivation at the end of a few days' use. I have not doubted, since noting the above fact, but that it holds in solution some little mercury, and I have been convinced of this fact by the three following experiments":—

The details of these experiments here follow, but are too long to be repeated. However, here is the conclusion, which is quite interesting:—

"Mercury thus rises in dissolution, in vaporized form, with the gas. It also remains suspended, at the temperature of the atmosphere. Physicians may, perhaps, hereafter possess themselves of this method of presenting mercury in a very minute state, and may thus administer it to their patients in a very agreeable and convenient form."

This note of Chaptal has no great significance, inasmuch as it relates only to two isolated cases; but it at least serves to illustrate the progress made in men's minds relative to medication by oxygen.

It is with a view to follow the chronologic order of ideas, rather than of dates, that we have postponed the advent of Fourcroy.

We were just now at Montpellier, engaged in following some clinical experiments on phthisis. It is entirely natural that two or three years from that time we should find an original work on the same subject, and issued by the same school. We at once accord to it the place it deserves to occupy. The researches we are about to exhibit are the counterpart of those which we have heretofore analyzed, in treating of the physiologic action of carbonic acid. They were made in the same spirit and to the same end, to wit, to attempt to produce phthisis artificially, by causing to be respired precisely the same gas that has been extolled as a curative in that disease.

Dumas, of Montpellier, in 1792, in the notes which accompanied his translation of the essay of Thomas Reid "On the Nature and Treatment of Phthisis Pulmonaris," gave the results

of some interesting physiologic experiments concerning the action of oxygen. After having pointed out two principal forms of phthisis, in one of which this affection occurs in nervous subjects endowed with a very irritable organization, who are then attacked with numerous spasmodic and inflammatory symptoms; or, again, in a system laboring under a condition of profound atony, and incapable of reacting for itself, and which ordinarily succumbs to the slow form of phthisis, Dumas believed that in the first instance the use of oxygen would have the most baleful effects.

"I think I can set forth," said he, "founded on experiments, that the continued use of such an air would start in the lungs that degree of lively irritation which sometimes leads to a tuberculous or ulcerous state, of which that disease is the necessary consequence. I have followed with some pains the experiments made with this view, on animals, and I am convinced that, subjected for some time to the action of oxygen gas, the lungs are irritated, become red, flushed, raw, and injured. The injured part forms a sore which extends, suppurates, and takes on an ulcerative character, and this becomes one of the sources of phthisis. I will give an account of the experiments I have made in this direction, on living animals, and which no one before me has attempted.

"I took a dog of medium size and perfectly healthy. I placed him under a large receiver, in which all the atmospheric air had been replaced by oxygen. I adjusted two tubular siphons to the receiver and fitted into the tube a stop-cock which I could open and close at will. One of the siphons served to discharge the air charged with oxygen gas in proportion as it was polluted by the respiration of the animal. The other opened into a second receiver, to renew, as required, the quantity of oxygen which was lost. In this manner I was able to maintain a constant purity in the air of the receiver, and to preserve in it at all times the same quantity of oxygen. My apparatus thus arranged, and the dog placed under the receiver full of oxygen, I kept him in this atmosphere, which he breathed, with scarcely any admixture, for the space of six hours. At the end of this time his respiration appeared to become more precipitate, more rapid, and the animal showed signs of uneasiness. I then removed him, and placed him in an atmosphere more dilute and better adapted to him. In the evening I repeated the same

test, and I repeated it twice a day until the twenty-eighth day, when the lungs ceased to work with the same freedom. It became necessary to shorten the time of the test, and I continued it for fifteen days longer, with the greatest difficulty. At this point the animal almost entirely lost the power to breathe and to cry out; his breathing became sonorous, sibilant, and laborious, the sound of his voice hoarse and stifled; his eyes appeared dull and drooping; he suddenly lost a great quantity of hair, especially about the chest; he fell away to the extent of a considerable emaciation, and I thought I saw in him all the indications of incipient phthisis; when I decided to kill him and open the thorax, in order to examine the state of the lungs, and to verify what I had at first forejudged.

"The cavity of the thorax having been laid open, I found the right side filled with acrid serum and much coagulated blood. The serum, thrown on burning coals, was dissipated in the air with the exception of a thin pellicle, which was puffed up in the form of a bladder and remained for some time attached to the coals. The coagulated blood presented a fleshy consistence, similar to that of the pleuritic buffy-coat, and it was limited to the upper portion of the lungs, corresponding to the bronchial tubes and trachea. The bronchial tubes themselves appeared to be filled and distended with it. The pleura was already tightly adherent to the lungs, especially at the bases, which were adherent to all the adjacent parts. The membrane was red, tumefied, and as if affected by inflammation. The lungs, red and seamed with little rents, had become considerably solidified, as occurs in the case of organs which have been for some time inflamed. Lastly, I found, in the vicinity of the bronchial tubes, a small suppurating sore, of which the hard and callous edges threatened soon to degenerate into ulcers. The anatomical inspection of these organs, therefore, did not permit me to doubt that oxygen had induced an irritating action upon the lungs, and that from it had resulted all the ordinary symptoms of phthisis."*

We have not hesitated to give this report in full, since it is one of the most interesting, as well as the most serious, which has been made on the physiologic and pathologic action of oxygen.

* Annales de Chimie et de Phys., 1st series, chapter xxix. (Extract from notes made by Dumas to the translation of Thomas Reid, on "Pulmonary Consumption.")

For all that, we do not implicitly accept the conclusions which might be drawn from these experiments, since, to be entirely conclusive, it was necessary that they should have been repeated, and not limited to a single animal. Such as they are, however, these investigations of the celebrated physiologist of Montpellier were, without question, up to that time, the most methodic, most ingenious, and most precise known to science on the subject of oxygen.*

We come at length to Fourcroy, and here beg permission to dwell, somewhat at length, on the ideas which this chemist advanced concerning the physiologic and therapeutic action of oxygen. Not that his labors have contributed much toward advancing the reigning tendencies, or the favorable impulse which they had received, but because they, to a certain extent, represent the epoch, and because they have left their impress upon nearly all that has since been published on this subject in France, and to some extent in foreign countries.

3. Fourcroy.—Among all the chemists and physicians in France, who have written on the medical use of oxygen, Fourcroy is assuredly the one who has longest occupied himself with this subject. He made it the absorbing topic of the greater part his life, and attached to it a capital importance. Therefore, for the reasons we have all along urged, and because this portion of the scientific work of Fourcroy has been entirely left in the background by most of his biographers, we will devote some space to this chapter.

In his "Dictionaire Historique de la Médecine," Dézeimeris enumerates with care a considerable number of more or less important memoirs, published by this eminent scholar, on physics, chemistry, and natural history, but refers to no special study of the medical use of oxygen; and in the biographic study of him (Fourcroy) by this historian, nothing is found which relates to this very interesting phase of the intellectual life of our chemist.

To show that we do not exaggerate the importance of this omission, we will at once state that the office which it seemed to him oxygen was destined to play in medicine occupied him for at least a score of years. Yet, why should it be strange? It had been but eighteen years since Priestley had finally isolated this

* The poor dog was slowly poisoned by being compelled to inhale, first, *chlorinated* oxygen, and, secondly, his own poisonous emanations.—Trans.

gas, for which the ancients had made a reputation in advance, naming it, without realizing its nature, *pabulum vitæ*. It did not take the philosophic mind of Fourcroy long to perceive the immense influence which so energetic an agent, and one so universally diffused, would exercise on the human economy. From that moment his course was decided; the germ of a vast study was in his mind. Which of the two, chemist or physician,—for, by observation and experiment he was both,—fertilized it? This we will presently endeavor to point out.

It is assuredly a settled matter of fact that for Fourcroy this study, these researches on the applications of chemistry to biology, take the lead of a multitude of works which have for posterity a far greater value. He, in fact, in a manner made it his *Philosopher's Stone*. Even more, he saw in it a *revolution!*

A little after 1789 he even indulged in holding this settled idea. It is he himself who says, in his "Mémoire sur l'Application de la Chimie à l'Art de Guerir," published in 1798: . . . "In a word, I long for an unmistakable revolution in the theory of medicine. I invoke it through my prayers; I have announced it for the past fifteen years in my lectures; I proclaim it in all my works; I will hasten its initiation with all my powers, with all my faculties; but I desire that it shall be a gradual, a deliberative, and judicious revolution," etc.

One will no doubt be surprised, at this distance, that Fourcroy found it so easy to make a revolution in medicine with a new remedy. But we must realize that he lived at a time when nothing was considered astonishing. Such were the political upheavals, and the marvelous revolutions of physical science, that men's minds were disposed to tolerate innovations. Therefore it was very tempting for a physician-chemist to establish a medical system.

Fourcroy really appeared to be thoroughly pervaded by his mission. But hear him, rather:—

"When one once realizes the necessity for discovering a true medical art, based on the philosophy of nature, in the better known laws of the intimate attractions which bodies exercise one upon another, one cannot be satisfied with the first result, which is so often confounded. either with the expression of prejudices, or with the errors born of hurried observation, if not joined with experiments upon the mode of action of the

medicament, as to the immediate effect which it produces in the functions of our organs."*

It is evident that he spoke of the present, and felt the necessity of raising to science a lasting monument, based on a union of experimentation and well-tested practice. We shall soon see how he carried out his programme. Meanwhile we will endeavor to show that he was somewhat severe on others; that is to say, toward scientists who seemed to him to compromise his scientific processes, or to follow in his tracks. It might be said that he reserved to himself exclusively, the domain of physiological and medical chemistry, and the daring hypotheses which were produced about him, in this order of thought, appeared to him as so many usurpations. Here is a curious example of it: After certain galvano-chemical experiments, somewhat carelessly made, Frederic Humboldt—the same who afterward, having won a great name in science, a little later was to be called *Alexander von Humboldt*—was induced to assume, still more inconsiderately, that "*the most powerful stimulus of nervous fibre is an alkali. It appears that it is through their nitrogen that these salts play this part in the irritable and sensory system. . . . It is this alkali which, diffused throughout the system, plays the part of a salutary stimulus to animal fibre. It is by this that I explain the ferocity of ichthyophagous tribes.*" †

Fourcroy considered these conclusions somewhat premature and fairly questionable, without realizing that they were decidedly rational. He feared that this scientific rashness might throw some discredit on his favorite studies. Hence he wrote to Van Mons on the subject of these experiments: "I fear that M. Humboldt goes a little too far in his explanations. . . . I think that if chemists continue to exaggerate so much, physicians will protest, and not without reason, against the impiety of chemistry." ‡ Fourcroy had no doubt but that in saying this he severely criticised himself. His letter gained him a response from M. Humboldt, who defended himself indifferently, but above all expressed the liveliest admiration of his (Fourcroy's) labors, and his own anxiety to see at last the completion of the work on animal chemistry which he had announced. Thereupon, a new letter from Fourcroy, in which he answered

* *Loc. cit.*

† Annal. de Chimie et de Phys., 1st series, chapter xxii.

‡ *Op. cit.*, 1st series, chapter xxvii, p. 70.

in advance objections which could not fail to be made concerning his exaggerated pretensions. Thus he defended himself vigorously for desiring to give "a *complete theory* of animal physics, founded on modern chemical knowledge, and for still greater reason to establish, on the same basis, a doctrine of pathology." * He said he was too hasty in generalizing and in drawing conclusions from isolated facts. He added, also, to Rollo, a little hypocritically, intending, doubtless, an insinuation toward the speech of one of his rivals on the other side of the Channel: "What matters it if I repeat to you these too hasty applications to pathology and therapeutics, or if I recount to you the diseases newly classified as having a superabundance of hydrogen or oxygen, and of the remedies limited to oxygenators and deoxygenators, on which some modern enthusiasts are already attempting to adjust the whole healing art?"

Yet, as Fourcroy could not himself condemn his own ideas, he hastened to say: "Since a great truth, concerning the general composition of animal bodies, has thus far been discovered, is it necessary to believe that all truth has been secured, and that from these cursory glimpses, although they may be important, one can construct a complete system of medicine?"

It is a case of saying slyly to our author: "You are a goldsmith"—I am deceived; "you are a chemist."

Thus far we have seen in Fourcroy only a man who had in his head a great synthetic idea, who hesitated, who did not avow what he really thought, and who was constantly apprehensive that works on the same subject as his own would detract from his originality and cause him to be judged unfavorably in advance. It is time to show him at work, and to give a condensed and critical account of his labors on the subject which interests us.

The results of Fourcroy's investigations as to the part which oxygen plays in the animal organization and the therapeutic applications that can be made of it are found recorded in two memoirs, published at an interval of ten years,—one in 1789, on the properties of vital air; the other in 1798, on the application of chemistry to the healing art, etc. In point of practical results they are both of about the same importance, viz., almost null; but the latter work is very interesting in a speculative point of view, for the reason that it shows us by what series of chemical

* *Op. cit.*, 1st series, chapter xxvii, p. 70.

considerations Fourcroy reached the construction of his system, although he personally rejects the idea of a system. This is why we shall begin by studying the latter.

Let us see, then, what was the point of departure of our author as to his inferences concerning the medical properties of oxygen.

Here we cannot do better than to permit him to explain for himself the history of his ideas, for the additional reason that he has command of a native eloquence which we know we could not imitate should we ourselves undertake to describe his conceptions:—

"When in 1779 and 1780 Berthollet explained the causticity of metallic salts by their activity in releasing phlogiston from animal matter; when he showed that the aqueous solution of corrosive sublimate placed in contact with flesh is precipitated as mild mercury, while the animal matter became friable, it was thenceforth easy to perceive that the part at that time attributed to phlogiston was really attributable to oxygen, the action of which must have been in an inverse manner; that is to say, the corrosive sublimate yielded to the animal matter its oxygen in place of carrying away phlogiston; and it was thus that Berthollet, who, having in 1785, after the discoveries of Lavoisier, relinquished the theory of phlogiston and explained the action of metallic oxides on the organs of animals as caustics. It was at this period, and even at the close of 1784, that I began to present in my course, as a positive fact, that which I had, until then, announced as a thing still hypothetical. I showed by experiments that the metallic caustics (oxide of arsenic, red oxide of mercury, and gray oxide of silver) really burned animal substances; that they lost through these substances the principal part of their oxygen, and that these oxides thus returned to a metallic state. I even compared, at this same time, the action of fats, heated with metallic oxides, in the preparation of unguents; for the reason that it was natural to consider phosphorus and fats, so abundant in animal matter, as well calculated to enlighten us concerning the nature of the change which animal substances undergo in the presence of metallic caustics. Ere long I had pressed this idea still further in my lectures, by making it evident to the students that the energy of caustics was but the excess of medicinal potency. I began, in 1785 and 1786, to foresee that the action of some remedies might readily proceed

from the oxygen which enters into their composition. The study of the properties of this element, with which I was then eagerly occupied, showed me that it played an important part in chemical phenomena. Precipitated from vital atmospheric air into combustible bodies by the effect of the combustion itself, I showed that it was invariably characterized in its combustion with burned bodies, as the principal source of their odor and of their acridity, by pointing out to the young students the example of carbon, of sulphur, or phosphorus, almost tasteless in themselves, yet becoming sharp, piquant, even caustic, by the addition of oxygen; the example of arsenic, of copper, of mercury, of antimony, having, in their metallic state, but a feeble or no action on animals, but changing to the nature of irritants, of purgatives, of emetics, even corrosives, according to the proportion of oxygen combined with them in the various pharmaceutical manipulations to which they were subjected.

"Thus I advanced, little by little, from experiment to experiment, and from cogitation to cogitation, to consider the purgative, emetic, stimulant, fusing properties, as the first degrees, or progressive terms, of a graduation, or of a medicamental ladder, of which inertia and feebleness were the lowest round, and causticity, destructive of animal organization, was the maximum or summit.

"The objections which occurred to me, far from checking the march of my reason in this succession of ideas, only accelerated it, by the readiness and assurance which the chemical facts afforded me. Water, the most highly oxygenated of all bodies, since it contains 0.85 of it, has but very feeble medicinal action, because the element which fixes oxygen in it, the 0.15 of hydrogen which saturates it, retains it with too much force to permit it to act on animal matter; otherwise, instead of offering to man and animals the present form, which quenches their thirst and sustains their existence, nature would have given them an incendiary and destructive principle, even more disorganizing than the powerful mineral acids, of which chemical art has learned to effect the separation of the component elements, where they exist, or of the entire composition. What I have conceived as to the medical inertness of water I have simply applied to all bodies naturally or artificially oxygenated, which, notwithstanding the presence of oxygen, exercise but a feeble or no action on the organs of living animals.

"Thus, gradually, a second principle was evolved for me as

to the medicinal properties of oxygenated substances, to wit, that these are not really medicaments, or that they exercise no sensible effects in our bodies, except as they, containing oxygen, yield it more or less readily to animal matters with which they are brought in contact."*

Not wishing to misuse quotations, we undertake solely to maintain that Fourcroy's point of departure is purely chemical. This is precisely where the defect in his armor becomes apparent. There are certain oxides which comport themselves in a certain manner in a retort. Why should it be different in the animal organism? He does not say this in set terms, but this was undoubtedly his opinion. To him the medicinal property of a substance depended on the quantity of oxygen it contained, and, still more, on the affinity of this element for animal matter, and the facility with which it can abandon the compounds of which it forms a part, in order to unite with organized substances. For him the animal economy is, in reality, but a portable retort, in which oxygen may abandon at will this or that combination which retains it, and may betake itself, now to the stomach, now to the bowels. This idea is found on nearly every page of his memoir; it is dwelt upon persistently. But if Fourcroy had more carefully observed what becomes of certain oxides introduced into the organism, he would have seen that they are not all reduced to a metallic state, but that some of them operate less actively than the metal administered in a state of purity. In short, if he had earnestly observed the physiologic and therapeutic action of compounds rich in oxygen, he would have also seen that many of them do not appear to act in the slightest degree according to the proportion of oxygen they contain.

The theory of Fourcroy, as to the chemical rôle of oxygen, could not fail, in fact, to be tainted with errors and to lead him to inaccurate results, since it was based on facts, at least very hypothetical, if they were not absolutely false,—a necessary result of the very crude ideas prevailing in relation to the chemistry and composition of elementary bodies. Thus, he says that the first opportunity he had to verify the energetic action of oxygen was when, in his laboratory one day, two of his pupils, in preparing oxygenated hydrochloric acid, inadvertently inhaled a quite notable quantity.

It is unnecessary to repeat all the details of what Fourcroy

* Annales de Chim. et de Phys., 1st series, chapter xxviii, p. 298, 1798.

was able to observe on this occasion, since we are not treating here of the properties of chlorine; besides, the gas which had produced the symptom of acute coryza, observed by this witness, contained oxygen only theoretically.

Having seen that the imaginary oxygen of his muriatic acid possessed the property of thickening and coagulating animal fluids, Fourcroy found it very ingenious, and especially fortunate, with respect to local color,—I should say *medical*,—to interpose that old phenomenon of the *concoction of humors* in diseases, so honored and of so much importance in ancient medicine, in order to still give a glorious rôle to his universal oxygen.

"This concoction," said he, "consists in a uniform and homogeneous thickening of any given humor, an effect which cannot be mistaken for anything but a fixation of oxygen. . . . . Even the formation of pus comes into the same class, arises from the same cause, and obeys the same laws."

Nevertheless, this is what Fourcroy calls *searching for the true bases of medical science in the philosophy of nature.* Those symptoms of active irritation, caused by chlorine, opened to him infinite horizons as to the future of pathology and therapeutics. See what he had observed. As to his experiments,—that is to say, his clinical facts,—they are limited to the external application of his oxygenated muriatic acid to a cancerous ulcer, and the administration of the same internally, as a drink, in case of a patient afflicted with syphilis; in fact, to furnish proof of the excellent effects of this same fantastic acid, as an antiputrid, antiseptic and antivirulent, "thanks in every case to the oxygen with which it is surcharged," according to the felicitous expression of Fourcroy!

We were about to forget the oxygenated pomade, so highly extolled at this period, and which was prepared by causing nitric acid to react on simple cerate. This pomade was found to have wonderful properties in the hands of Fourcroy and other physicians of the period.

We will not dwell longer on this memoir of Fourcroy, which has not for us the importance which was attached to it by its author, on account of the exalted philosophic tendencies which it presented. We shall have something to say concerning the first work, relating to oxygen, published by Fourcroy.

Here, at least, we are on the ground of physiological and clinical experiment. But what can be the result of such iso-

lated tests and of clinical experiments so carelessly conducted? Evidently we can to-day accord them but very moderate value. Here we have a *résumé* of this memoir, "On the Medical Properties of Vital Air," read in 1789 before the Royal Society of Medicine, and of which an abstract has been given in the "Annales de Chimie."*

It considers a score of cases of phthisis treated by oxygen, and refers chiefly to diseases observed by Fourcroy himself, or to those of which he was able to gather the history, and in which the respiration of vital air brought about a very decidedly good condition, an improvement of the principal symptoms; in short, a change sufficiently evident to warrant the hope of an early and complete recovery.

But all these phenomena proved to be transitory, and at the end of two or three weeks of oxygen administration symptoms of violent inflammation supervened; the progress of the disease was from this moment more rapid than before, and consequently the fatal termination was precipitated.

Struck by these untoward results, Fourcroy sought to find the cause, and then thought it was quite time to experiment on animals. Here is one of his conclusions on the subject:—

"When an animal is immersed in a bell-glass filled with vital air, its respiration is accelerated, expansion of the chest considerably increased, and the heart and arteries contract more rapidly and with more force than in the natural state. The animal is soon in a really feverish condition; its eyes grow red and prominent, perspiration starts from every part of the body, and the temperature of every region is decidedly increased. In short, the subject is soon attacked with an inflammatory fever of an extremely acute character, which terminates in gangrene and finds its principal point of development in the chest."

The experimental result announced by Fourcroy accords so little with those of other observers, Priestley, Spallanzani, Morrozzo, Dumas of Montpellier, Beddoes, Broughton, and with our own, that it may be questioned whether the author of the memoir, which is the matter in hand, really caused his animals to breathe oxygen. The mistakes he has more than once committed in this direction warrant a certain degree of reserve in estimating the value of these experiments, and also with regard to the conclusions to be drawn from them. Fourcroy himself concluded

* First series, chapter iv, p. 83.

that "vital air starts a conflagration in the pulmonary vessels, and thus turns on a torrent of heat which produces all the symptoms above described."

It is in almost the same terms that we have been answered by more than one physician, and by more than one chemist, to whom we had made known our intention of employing oxygen in our practice:—

"The action of vital air on the respiration being well established, and the active heat which it excites in the lungs being the base of this action, Fourcroy thought that if its use was contra-indicated in all diseases in which heat and vital activity are already too energetic, it would be useful in all affections characterized by a sensation of cold and sluggishness of movement. He has seen good effects in the chlorosis of young girls, in scrofulous affections of children, in puffiness of the abdomen so common at this age; in chronic and humid asthma, in obstruction of the bowels, hypochondriac affections and commencing rachitis; in obstinate dyspnœas, accompanied with pallor of the skin and general weakness. These favorable effects in these diseases are manifested by a very perceptible heat of the skin, by the coloration of the face, and by the acceleration of the pulse. These symptoms go on increasing until, at the end of several weeks of the use of vital air, there results a veritable feverish movement, an augmentation of activity in the tissues, the influence of which in the cure of chronic diseases is no longer a question with physicians accustomed to observing the progress of nature in the spontaneous cure of many diseases."*

Doubtless in the foregoing there are valuable indications and correct inductions, but we would wish to find in Fourcroy something more, such as clear and explicit observations and well-scrutinized clinical facts. As we showed before speaking of Fourcroy, these adventitious ideas were already known to science, and had been formulated in a manner at least quite as precise. And it is, moreover, the only really valuable point there is for us in the works of Fourcroy. These fifteen or twenty lines, which contain nothing which had not been said before, contain more science and less conjecture than is found in the two dissertations of Fourcroy.

Upon the whole, however, the theory of Fourcroy, erro-

* *Loc. cit.*, p. 83 *et seq.*

neous as it might be in a chemical, and, above all, in a medical point of view, indicated a loftiness of view very remarkable; and, not to consider it from a chemical stand-point, it shows what this scientist would have been capable of had he appeared at a later period. Most certainly it was not an ordinary idea—that of following oxygen into all the compounds of which it forms a part, and studying the active relation it carries with it in the combinations into which it enters.* But before studying this special action of oxygen in a given compound, it is necessary, in the start, to be quite sure that it really takes place, and not run the risk of attributing to Cæsar what pertains to Pompey—I mean, to oxygen that which was the effect of chlorine, as happened with him; for example, in case of muriatic acid and the oxygenated (oxygen-bearing) muriates of mercury. But we do not hesitate to say, as bearing upon the exoneration of Fourcroy, that his theories, however ingenious, might be, to some extent, condemned in advance, considering that it was impossible to make a philosophy of chemistry before this science had been actually established.

4. The School of Fourcroy.—The influence of this pseudo-chemistry, which we have perhaps already considered at too great length, was, furthermore, detrimental to the future of medicine, which appeared to be on the eve of initiating the use of oxygen. As always occurs in such cases, his imitators went still farther than he. We will review them as rapidly as possible, since there is so little of value to the healing art in all these systematic essays which we are about to enumerate.

In 1797 Rollo published in London, in connection with Cruikshank, as to the chemical part, his "Histoire de Deux Cas de Diabete Sucre," etc., etc.,† in connection with which he yields himself to the fancy of personally founding a medical system. The doctrine of Rollo leads at once to that of Beddoes and to that of Fourcroy. Beddoes, having put forth the hypothesis that in phthisis the system appears to be surcharged with oxygen, while with scorbutics there is, on the contrary, a deficiency of this element, Rollo suddenly conceived the idea of classifying diseases according to whether they are caused by superoxygena-

* In order to have a more complete idea of the chemical nature of oxygen, as Fourcroy understood it, it is necessary to read his sketch of "Oxygenology," in the Encyclopédie Méthodique, part, Chim., art. "Gaz. Oxygene," chapter iii.

† An Account of Two Cases of Diabetes Mellitus, etc., etc. London, 1797; two vols., 8vo.

tion, or, forsooth, by deoxygenation of the blood; and then he arranged, in his pathologic outline, phthisis beside diabetes, which was to him the highest manifestation of superoxygenation of the blood. Next, Fourcroy admitting that oxygenated substances do not act in the capacity of remedies except by reason of their oxygen, Rollo assumed that remedial substances are but moderately complex in chemical composition. They are superoxygenators and deoxygenators. Behold nosology and therapeutics reduced to their simplest expression!

Rollo did not adhere to this in his indifferently successful innovations. Having read various reports of the good results obtained by the use of nitric acid in venereal diseases,* he saw in this the special agency of oxygen, and boldly concluded that, in these affections, mercury could be advantageously replaced by oxygenated substances. But, finding the method of administering oxygen through the respiratory passages too uncertain, he believed it quite preferable to reach the same result by giving nitric acid, citric acid, chlorate of potash, and particularly the *oxygenated muriatic acid.*

This portion of Rollo's work was actively combated by Benjamin Bell,† who affirmed that nitric acid did not succeed in any cases in which it was employed.

Bell believed that this remedy was wholly useless, and he attributed the success obtained during its administration, not to its real efficacy, but to certain causes which were not yet well known, and which frequently result in spontaneous dissipation of various venereal symptoms (buboes, for example), without reference to any remedy.

In short, this author thought that nitric acid, used either externally or internally, had no properties differing from those of other acids.‡

It was under the inspiration of the ideas of Rollo, whose work on "Saccharine Diabetes" he had just translated, that Alyon published, in 1798, an essay on the medical properties of oxygen in venereal diseases.

It is useless to repeat what this pupil of Fourcroy understood by oxygen. After Alyon came Fournier,§ who, in a paper read before La Société de Méd. de Paris, sought to prove that

* *Op cit.*
† A Treatise on Gonorrhœa Virulenta, etc., 2d ed., Edinburgh.
‡ Reçueil de Littér. Méd. Etrang., chapter i, p. 227.
§ Journal de Sédillot, chapter v, p. 358.

mercury acts in venereal diseases only through the oxygenation which it undergoes during the various processes to which it is submitted in preparing it for administration. This is why he used with confidence, and, as a matter of course, with success, this same nitric acid. Nothing short of tetanus, even, did he fail to cure with this universal specific.

But, patience! Note the progress. Some years later, nitric acid no longer curing, Burdin * conceived the idea of administering the ethers in various diseases of the chest, under the pretext that they contain much oxygen.

It would take too long and be fairly wearisome to continue this dry enumeration. We had desired to devote a few lines to Baumès, who, in his "Nosology," advanced to its apogee the doctrine of which we have outlined the history.†

But why should we care to add to all that we have just recounted a tableau of the *Oxygeneses*, the *Hydrogeneses*, the *Phosphorigeneses*, etc.?

After all, in all these attempts somewhat fantastically made by the imitators of Fourcroy, we perceive that at each step it was a question of oxygen; yet we nowhere find much done with it; or, rather, their writings are so full of it that if they did not administer it to their patients it was not from lack of purpose. This gas was a kind of Proteus, whom they thought they could possess and control at will, but who continually eluded them. See, nevertheless, when it fell to Fourcroy, against his will, to banish oxygen from therapeutics—he who had been one of its most ardent advocates!

It is now time to return to the domain of observation and experience. It is in England we shall find these, and it is Beddoes who is to restore us to the true line of investigation—that of physiology and clinical medicine.

5. Beddoes.—At a first glance, the work of Beddoes‡ appears somewhat confused, and, in fact, this confusion really exists, as regards the arrangement of his materials. It is evident that the author was not preoccupied with the idea of making a book. He experimented extensively, has given the result of his experiments, and, as a consequence, has grouped in some disorder, and almost in the same manner in which they

* *Op cit.*, chapter x, p. 144.
† Baumès, Fondements de la Science des Maladies, vol. iv, 1802.
‡ We speak of the chief volume,—Considerations on the Factitious Airs, etc.

were produced, the clinical facts of which he was a witness, or that were reported to him by persons whom he believed to be both competent and worthy of credence.

Notwithstanding this, one is struck, at the very outset, by the really scientific character of the work,* particularly the first part. Beddoes at once displayed that originality which grapples the subject in a much more practical manner than Fourcroy, and showed that he knew how to shun the reef on which the physiologists of his day had fallen. Indeed, at this very time, there were some efforts toward an experimental study of the respiration, but constantly revolving in the same circle. Thus it was eagerly desired to learn the exact numeric relation between the differing quantities of gas inspired and expired. Without doubt this inquiry was very important, but one does not sufficiently realize that the analytical processes, at the time known to chemistry, were insufficient to arrive at very precise results, without considering that the exact composition of known bodies was still very imperfectly determined, as is made very apparent by the radical errors of Fourcroy. Thus, we see Beddoes attempting physiological experiments; but he did not suggest that their object was to learn what quantity of carbonic acid a man expires in a given time, or what quantity of air enters the lungs at each inspiration. He started from a certain fact: Oxygen is the vital principle of the air;—and asks what effect would be produced by an atmosphere which contains two, three or four times as much of this vital principle as common air. Reasoning, and the laws of physiology, as he understood them, made him foresee, or preconceive, a general excitation, an increase of action throughout the entire economy, and an increased degree of vital resistance. Experiments on animals and on himself, added to those of other observers, confirmed him in this conclusion. It remained to utilize, for the benefit of therapeutics, an agent so widely disseminated, and which possessed a potency of which he yet had but a general idea. It is already seen how different his setting out from that of Fourcroy. We can readily summarize as follows: Fourcroy, physician by force of circumstances, was chemist by taste and by the special tendencies of his mind. Beddoes, physician first of all, and especially a pupil of Brown, was, in case of need, professor of chemistry, when the

* In comparison with the more or less insignificant attempts made by other authors.

opportunity presented itself at Oxford; but at the same time he had not forgotten that Boërhave, little suspected of partiality on a similar subject, had said of chemistry, "*Optima medicinæ ancilla, domina pessima.*" [To medicine the best of servants, the worst of masters.]

Hence, he asked of that science only what it could give with a degree of certainty—gases well defined, easy to prepare, and concerning the nature of which no mistake was possible. From physical science, at that time so creditably represented by James Watt, he demanded convenient apparatus, in order to easily manipulate the gas, and to render its application as practicable as possible. Thereupon, guided by his physiological experiments, and by inductive considerations which were not wanting in precision, he undertook, not to found a new medical system, not to insist upon curing all diseases by the inspiration of any given gas, but to solve some therapeutic problems. It occurred to him many times, as to all who practice the profession of medicine, to find himself in the presence of a case in which all ordinary means had failed; against which he had, as it were, pitted in vain the entire arsenal of therapeutics. In the presence of such cases he was certainly at liberty to have recourse to a more heroic remedy than either oxygen or hydrogen. Finally, these gases had but lately been discovered, they had scarcely been utilized as remedies, and hence there were the best of reasons to await some practical evidences of efficacy. Some isolated successes encouraged Beddoes to continue his clinical experiments. He talked of them to his friends, who, on their part, in the absence of better, tried the new treatment; and thus, little by little, pneumatic medicine took form in England. Yet, if the sum total of facts observed by Beddoes and his partisans seemed to establish a system of doctrine, this is not quite true except in appearance. From time to time we find, in his "Considerations on the Factitious Airs," some idea of generalization, though ordinarily comprising but a very limited number of cases.

To show that Beddoes did not make his experiments and did not establish theories upon notions assumed in advance, nor without entirely systematic observation, it is sufficient to cite what he wrote to Dr. Rollo in 1797, as reported in his "Treatise on Saccharine Diabetes:"* "I have, at present, no chemical

* Rollo and Cruiksh., On Diab. Mell., vol. ii, p. 8.

theory of disease; my opinion as to scorbutus, which seemed to me quite plausible, and which is in accord with the opinions of Dr. Trotter, is contradicted by facts."

It is seen by this avowal what a stride he made in advance of all theories, particularly of his own, and how willingly he sacrificed them when he could not reconcile them with facts. This declaration of faith ought to be taken into serious consideration by the critic, since it is a guaranty of the reliability of the experiments presented. In certain portions of the principal work of Beddoes, the circumstantial reader of to-day would find, possibly, a slight tinge of charlatanism; since in our day we both use and abuse this mode of intercourse, in order to take advantage of the credulity of the public; but the impartiality of the author suffices to convince us of the authenticity of his observations, corroborated, as they are, by sufficiently well-known names.* The only criticism which we might make is that they are often lacking in perspicuity, especially as to the diagnostic aspect of the disease; which lessens the value of the results obtained, or at least makes us a little distrustful in many instances. It is true that this department of medicine, the science of diagnosis, to-day so precise in a majority of cases, thanks to the proficiency of auscultation and percussion, was then very little advanced. Hence, one was frequently obliged, in describing a disease, to mention only the most apparent symptoms with their principal modifications, and afterward the final result.

We think we have said enough concerning the work of Beddoes, considered in general. Let us inquire into details, and analyze, successively, his two principal works.

In 1793 Beddoes published his first work on pneumatic medicine, in which he gave his ideas and his observations concerning the nature and treatment of gravel, scorbutus, consumption, catarrh, and of fever; as well as other studies in physiology and pathology.† About the same period Dr. Trotter, already favorably known, through his inaugural dissertation, "De Ebriatate Ejusque Effectibus, in Corpus Humanum." ‡ which won for him strong eulogiums from Cullen, published the

* It is sufficient to cite Ferrier, Thornton, Erasmus Darwin, Crawford, Carmichael, Gimbernat, etc.

† Observations on the Nature and Cure of Calculus, Sea-Scurvy, etc., Bristol, 1792; *Ibid.*, London, 1793.

‡ Edinburgh, 1786.

second edition of his observations on scurvy, in which he shared the views of Beddoes concerning pneumatic therapeutics.

Beddoes and Trotter, although admitting the same general opinions concerning the favorable results from the use of oxygen in the treatment of scurvy, had not, at the same time, exactly the same opinions concerning the nature of this affection. Trotter attributed the disease to insufficiency of oxygen in the blood only; whereas, to Beddoes, the entire system was deoxygenated, and to prove this he cited the discoloration of solids and the rigidity of the muscles and tendons. He also inferred that oxygen must be necessary to muscular contractility, and that it then entered into some new combination. Nevertheless, he admitted that the ultimate cause of the accelerated respiration following violent exercise is the necessity for restoring to the organism the oxygen expended, and this, he added, explains a variety of transient scurvy which occurs after a tempest, during which the seamen have been greatly fatigued. Death, in case of scorbutics, observed Beddoes, frequently appears to supervene because the blood is incapable of stimulating the left heart, the muscular fibres of this organ finding themselves wanting in irritability, and the blood deprived of oxygen.

It would require too much space here to illustrate, in detail, the ingenious inductions of Beddoes concerning the nature and causes of scurvy. The most important conclusion of this preliminary study was that oxygen is the inciting agent of muscular action.

Then he set forth his views concerning the formation of fat in the animal economy. The theoretical conclusions which he presents on this subject are certainly questionable. Here is one, however, which appears to be corroborated by quite curious facts. He admits that there is a constant tendency in the organism to excessive formation of fat whenever there is a deficiency of oxygen. Now, Dr. Trotter has observed that when a negro becomes rapidly *embonpoint*, we can easily estimate in how short a time (if we may thus express it) he will be attacked by scurvy. Furthermore, on a vessel carrying a sufficiently numerous crew, the only individual whom we saw affected by scurvy was a young sailor of remarkable corpulence. The emaciation produced by acids, taken in excess, and the rapid disappearance of obesity under an exclusively vegetable diet, demonstrate that this treatment is similar to that for scurvy.

The application that Beddoes made of his theoretical ideas on the oxygenation of the blood, to the study of phthisis, seems to us worthy to be noticed.

A fact long since accepted by science, and admitted as such for nearly a century, is that pregnancy, supervening in a woman attainted with phthisis, temporarily arrests the course of the affection, only to accelerate its progress after delivery. Among the many explanations given of this phenomenon, that of Beddoes may be cited as one of the most ingenious:—

"The blood of the fœtus," says he, "is oxygenated through that of its mother, through the intermediation of the placenta. Now, during pregnancy, which necessitates an increase of the absorption of oxygen, since there are two beings who are respiring, yet the lungs are performing their function in a manner to receive less and less of it on account of the growing obstacle to the action of the diaphragm. If, therefore, the lessening of the quantity of oxygen absorbed is the effect of gestation, is it not precisely this which arrests the progress of phthisis? and if it is thus, does not this argue an excess of oxygen in the organism of consumptives? Following this hint, should we not be able to point out a treatment for this fatal affection?"*

If Beddoes, instead of relying on theories almost exclusively chemical (a thing which did not often happen to him), had begun by carefully studying the physiological action of oxygen, and then its action on wounds, as he did later on, he would doubtless have had a more satisfactory explanation. In any case, he would have certainly comprehended that since the same quantity, or even less, of oxygen is addressed during gestation to a much larger sanguinary volume, the pulmonary capillaries must find themselves much less liberally supplied with oxygen during this period, and consequently the action of this gas on the pulmonary lesion resulting from tuberculization, supposing there is a cavity, or on the part of the organ affected simply with the inflammatory diathesis, must be less exciting. Let us add to this that the blood is, during gestation, charged with a much greater quantity of carbonic acid than in the normal state, and that we think this gas possesses a manifest property of inducing cicatrization.

We give these speculations for what they are worth, since

* *Op. cit.*

there are still many things unknown, even at this time, as to the manner in which gases act on the organism.

In view of the results of the unfortunate attempt that Fourcroy made with oxygen on consumptives, Beddoes admits the possibility of two conditions: 1. The inflammatory diathesis can change the structure of the lungs in such a manner as to cause them to yield more than a normal quantity of oxygen to the blood. 2. Or else, some cause which we have overlooked having rendered the lungs competent to absorb or the blood to attract a greater quantity of oxygen, a pulmonary inflammation may follow.

In short, Beddoes believed that a special phlegmasia, which is peculiar to phthisis, depends on this, that oxygen is gradually absorbed into the system in slight excess. He concludes from this that the regimen for phthisics should be exactly the opposite of that for scorbutics; for example, salt meats, and, above all, an oleaginous diet. Further, we must diminish or seek to diminish the quantity of oxygen introduced into the lungs by causing patients to inhale air with nitrogen and hydrogen added, and, by making them sleep in confined apartments, maintaining a sufficiently low temperature.*

We have dwelt somewhat at length on this work of Beddoes, and have done it designedly, since it is this which contains the most theories without, for all that, presenting, as a whole, any appearance of consistency or systematic arrangement.

These theories, we can easily understand, were well designed, from their extreme novelty, and by their originality, to pique the curiosity of the medical world. Fortunately, as we have already remarked, that was an age when the most astonishing discoveries succeeded each other with remarkable rapidity. Hence, this species of revolution in therapeutics was not generally received with indifference and incredulity, as would have been the case had it been announced in one of those moments of scientific apathy, of intellectual halt, so to speak, which seem to be an inevitable law of progress. Beddoes' work, and even that of Dr. Trotter, was mentioned with commendation by the most authoritative medical periodical of the time, the *Medical and Philosophical Commentaries*, edited by Dr. Duncan, and, to

* We are far from admitting all the theories of Beddoes, and particularly as regards this paragraph we take exceptions. It is evident that here our author has been a little too positive. We expect to show, on the contrary, that in a number of cases of tuberculization oxygen is unquestionably indicated.

judge of the importance of that which was last given them, we say that he placed them in the same rank with works on galvanic electricity, the discovery of which was quite recent.*

Encouraged in his efforts at therapeutic innovations, Beddoes gave himself up to patient research in this unexplored field. But he quickly realized that if limited to his own unaided resources he scarcely possessed the means to carry out earnest and profitable experiments in behalf of science. Therefore, he desired to found, by national subscription, a special establishment for the treatment of diseases by means of the gases,—an idea that Wedgewood had already entertained during the last days of his life. With this object in view, he explained his project to the manager of the *Medical and Philosophical Commentaries*, who gave it his unreserved approval. Thus, the next year, in the periodical publication of Dr. Duncan, to an article entitled "Nouvelles Diverses," this note appeared:—

"Dr. Beddoes, already well known to the scientific world through some original works, has just proposed, in a circular, an establishment for the study in a thorough manner, of those powerful agents in disease, the elastic fluids, and for the discovery of the best methods of preparing and applying them.

"That the various elastic fluids, acting on the organism through respiration, exercise an immense influence, no one can deny. The recent experiments of Dr. Beddoes and other practitioners prove conclusively that the application of the elastic fluids (gases) to the treatment of diseases is, at once, quite feasible, and promises very favorable results. It remains, then, to determine clearly with what degree of success it can alleviate human suffering, and it is a subject which claims attention, not only from practicing physicians, but also from all philanthropists. We therefore have the firm hope that this laudable research will meet with the encouragement and success which it merits."†

We have sufficiently set forth the theories of Beddoes in phthisis, as well as the circumstances under which the establishment of the Pneumatic Institute was proposed, for the purpose of doing justice to the method, all of which had been translated in France in one of the most valuable reports of the period. "I will mention that Dr. Beddoes, the learned professor of chemistry in the University of Oxford, in bringing to perfection

* Med. and Philosoph. Comment., chapter xviii, preface and p. 86.
† *Ibid.* chapter xix, 1794.

pneumatic chemistry, has recently made application of it to a system of cure which he proposes as a specific for pulmonary phthisis. Constant and repeated successes have induced the English government to establish in London a hospital especially adapted to pursue and increase the advantages of a discovery so valuable to humanity."* Yet, from the outset, Beddoes never claimed that he had discovered a specific against phthisis; besides, the government had not taken the initiative in the matter, since the Institute was founded by popular subscription.

While the project of the Pneumatic Institute was gaining favor in the popular mind, the first edition of "Considerations on the Preparation and Medicinal Use of the Factitious Airs"† was published—a most curious work, and one which assuredly deserves to be better known than it is; at least, in France.

As we remarked at the beginning of this chapter, this work is not a didactic treatise; it is a collection of observations, arranged often without order, and in which are shown the results of treatment by oxygen, carbonic acid, hydrogen, hydro-carbonate, even by charcoal, and other medications which have nothing in common with gases; the whole preceded by physiological experiments on animals and accompanied by descriptions of apparatus devised by James Watt for the preparation and administration of factitious airs. We ask, at the outset, why this complete absence of system in a book which should have possessed it in a positive degree? It is evident that Beddoes wished to avoid, as much as possible, a dogmatic air of having established a new medical system. He had sufficient tact and intelligence to comprehend that a structure of that kind could not be the work of a single individual. Then, again, this was not the object toward which he directed his efforts. His object was to encourage the trial of remedial agents which seemed to him calculated to render great service to mankind; and, after having earnestly invited the medical public to test this new therapeutic agent, his satisfaction was not wholly at knowing that his views were accepted, but that his advice was followed by the most competent men. He made so little claim for the gases, and had so little idea of making them a panacea, that he believed it proper generally to commence treatment by ordinary remedies appropriate to the disease, and not to have recourse to the gases except

* Magasin Encyclopédique, chapter v, p. 469, 1795. (Article by A. Fardy.)
† Bristol, 1794; 3d ed., 1796.

when the former were insufficient. He had no desire that we should have blind confidence in these new remedies from the mere fact that some successes had been obtained with them. Thus, after having reported a case of chlorosis and two cases of asthma, in which the administration of oxygen had brought about a rapid cure, Beddoes, far from going into enthusiasm over the gas, still doubted.

"We can admit all these results," said he, "and consider them as corroborated; but other remedies—ether, for instance, would it not have produced similar results? And even this same result, to what extent is it specially attributable to oxygen? If we would be logical, we must not concede such efficacy until we have made a considerable number of comparative experiments."* Besides, just at the moment of presenting a certain number of favorable experiments, he goes further and says: "Skepticism is sometimes associated with the enthusiasm of investigation; at other times with a lethargic apathy.

"The following pages, therefore, will not be found more thoroughly incredible to the reader than to their author. I do not see, in fact, how, without honest skepticism, and without feeling a genuine love of research, it is possible in any branch of knowledge whatever to avoid mistakes and arrive at the truth."†

These well-chosen words are, in short, the candid expression of Beddoes' opinions, and show what a commendable spirit of criticism presided over his investigations as to the therapeutic utility of the gases. Notwithstanding this, he did not escape being made the object of sharp attacks in the medical journals of the day, and it was doubtless this fact which decided him to keep himself more and more in the background of everybody's work, repressing himself as much as possible, especially when this was necessary to the proper rôle of commentator. This is the reason why, in his "Considerations of the Factitious Airs," the only portion which may unquestionably be considered Beddoes' own proper work is the physiological part. The experiments were numerous and varied, and were made with different gases, and even with gaseous mixtures. In the course of this work we have already had occasion to speak of the divers results which he obtained with carbonic acid. We will revert to this subject in treating of the action of oxygen.

* Considerations, etc., etc., part i, p. 80.

† *Op. cit.*, part iv, p. 13 (preface).

To avoid dwelling longer on our own personal experiences, let us say a few words as to the principal conclusions at which he arrived concerning the physiological action of oxygen. To avoid repetition, we will not even mention anything except the facts which specially belong to him, or which, better than any one else, he demonstrated :—

"Oxygen very decidedly combats asphyxia. Whenever the blood has been more fully saturated with oxygen than in a normal state the subject is better adapted to endure the absence of respirable air, and even the effects of an irrespirable gas.

"Animals which have respired oxygen resist for a longer time the effects of refrigerant mixtures.

"The action of oxygen appears to be localized, principally in the muscular system.

"Oxygen is in the highest degree a promoter of (normal) irritability of the heart and vascular system."

With respect to therapeutic results, since we are not discussing a system, but citing facts, it will suffice that we give some figures :—

Thus, in twenty-two cases of asthma treated by oxygen, there were ten cures; in nine there was marked relief, and in the three others no amelioration.

In seven cases of chlorosis, five patients were cured and two relieved.

Again, we owe to oxygen five cures of rebellious cutaneous diseases, which were diagnosed by the author under the name of leprosy.

We will desist as to these statistical details, since further on we shall find a table which sums them up and completes them. Meanwhile, before leaving this subject, we will mention that Beddoes did not fail to describe three cases of epilepsy in which oxygen not only had not the slightest good effect, but even caused some passing disturbances.

This is not the place to inquire into the value of the clinical and physiological facts which were derived from the labors of Beddoes, since the results of our own experiments, in many particulars, conform to those of this author, and we shall be able to discuss them to better advantage when this part of the subject is specially considered.

Upon the whole, behold a man who conceived the idea of utilizing the action of gases for therapeutic purposes. The idea

doubtless was not entirely new, but it was in its practical application that it was original with him. Then, since it is necessary to give a creed to all people of whom we desire the confidence, starting from some very positive facts, he risked nothing in advancing some theoretic fancies and some general views. He did not stubbornly cling to any of them. He was ready to withdraw them when science demanded it, but he announced them, because some sort of substratum was necessary for the innovations which he wished to inculcate, and because it was necessary that every physician who wished to adopt them should have, in default of any personal conviction, the opinion of another. Thus we discover the origin and motive of the first work of which we have spoken. The innovations made their way, not without obstacles, not without many instances of deception; but since, on the whole, it was a true contest for therapeutics, success came, and the major part of the fortunate or unfortunate results of these trials were referred to him who was the originator and promoter of them. It became therefore a temptation to found a medical system. One has a certain reputation, or a plausible theory, perhaps, so easily exploited! Besides, the pupil had the example of the master, Brown, who himself had also wished to leave behind an edifice. He (Beddoes) did nothing of the kind. This author was content to report and to thoroughly scrutinize his physiological experiments, and he published them with all the observations which were sent to him, a few from all sides, even from France. Therefore he was very modest with his theories, and in all his comments, which he at times adds to these, he insists chiefly upon the practical side. As to explanations concerning the essential action of the remedy, he gave them only with the greatest reserve, and he was foremost to speak of the slight foundation which they had. This was the spirit of his second work. Hence its influence was immense. New notes and new observations were sent him in great numbers, sufficient to fill two or three volumes, wherefore the desired effect was produced,—viz., a decided impetus was communicated to pneumatic therapeutics. Thenceforth everything made Beddoes hopeful that medication by gases would have a happy future. For this reason, of that considerable number of cases, scarcely more than three or four were published. He preferred more positive results, rather than to repeat the same facts; more weight, fewer numbers.

"In the 'Considerations on the Factitious Airs,'" said he, in 1799: "I demonstrated by sufficiently numerous examples that the occasional administration of modified air was very practicable, and some cases proved in a very convincing manner the efficacy of the treatment. But in a majority of observations the most scrutinizing investigations are indispensable in order to determine the exact part attributable to the gas, in connection with the favorable results, and my intention in publishing them has been to encourage a trial of these methods in cases where all others have failed."*

No one could be at once more modest or more sincere. This did not prevent him from being made the subject of the severest criticism, as happens to every one who dares to advance such an original and auspicious theory. Without mentioning the caviling which sought him out, with reference to his experiments,† they even went so far as to contend with him for the honor of having revealed Mayow to his compatriots, notwithstanding the dates spoke so much in his favor. Hence he speaks in some places with a certain bitterness, quite appropriate, "of the honors due to the authors of useful discoveries, rather than to those amateur physicians who have done nothing for the advancement of medicine, and whose reputation, based on the opinions of incompetent persons, is equivocal and usurped."‡

In spite of this he never departed from his impartiality in scientific matters, and he gives a fine example of it in extolling its use in the blue-nail (digital cyanosis) of phthisis. The remedy was at that time (1798–99) very much in fashion in treating this affection. Beddoes, who, two years previously, had highly recommended the use of hydrogen, who had also published cases of cure of this disease (phthisis) by oxygen, by carbonic acid as well as by hydrocarbonates, was witness to very convincing facts in favor of digitalis, and took pains to announce that this method of treatment seemed to him to be quite efficacious.

We think we have said enough to make plain the interest which attached to Beddoes in the history of the application of the gases to the healing art. We can see what a happy advance

* Contributions to Medical Knowledge, p. 333.

† See especially Med. and Surg. Rev., 1796, and Jour. of Phys. and Med., same period.

‡ Essay on Phthisis.

followed the brilliant efforts of this author, but, since no one is a prophet in his own country, it followed that after his day his method was abandoned. Hill, a contemporary of Beddoes, it is true, published a very interesting work on the medical use of oxygen,* containing the history in detail of nineteen cases of various affections successfully treated by this gas. It is only to be regretted that the diagnosis of the several diseases so treated was not, in general, in the work of this author, given with that precision and clearness so desirable, and without which it is impossible to draw, from obtained results, legitimate therapeutic deductions.

Aside from two or three physicians of our time, who have attempted with numerous revivals, in England, to reinstate to a position of honor the cause of pneumatic therapeutics, especially medication by oxygen, the effort of Beddoes remains without followers, and neglect and oblivion long since claimed the labored and original work of our author.

6. OXYGEN IN GERMANY AND AT GENEVA.—However extended this history already, it would not be complete if we omitted to mention, as succinctly as possible, the career of pneumatic medicine in Germany and at Geneva.

In Germany attention was aroused to this subject, principally by the investigations of Ingen-Housz, and numerous experiments did not fail to be made. A little later, indeed, appeared the work of Mensching ;† then came Stoll and Ferro,‡ who adopted the new ideas with considerable enthusiasm, and defended them vigorously, particularly the latter. They were opposed by Scherer, § and then followed a most curious polemical discussion, between Ferro and Scherer, as to the medicinal use of oxygen. Hufeland || showed himself equally favorable to pneumatic therapeutics, and the happy results of which he was the witness so fully convinced him, that he both recommended it in his journal and himself employed the treatment by gases. Another author, who at this time made more noise than his

* Practical Observations on the Use of Oxygen. or Vital Air in the Cure of Diseases. London, 1800.

† Dissertatio de Aeris Fixi et Dephlogisticati in Medicina Usü. Goëttingue, 1787.

‡ Essai sur Quelques Medicam, Nouveau : Vienna, 1792. Et Sur les Effets de l'Oxygene, 1793–95.

§ Des Effets Nuisibles de l'Oxygene Dans les Inflammations Chroniques de la Poitrine. Vienna, 1793.

|| Journal de Méd. et de Chirurg. Pratiques, de 1790 à 1800.

predecessors, was Girtanner. He was more noticed because he advanced theories half chemical and half medical, in which was found, slightly modified, the ideas of Kirwan, of Beddoes, and even of Fourcroy.

Girtanner was one of the first to adopt and defend the new theories of pneumatic chemistry, and he did this principally in his "Elements de Chemie Antiphlogistique,"* which unfortunately has never been translated. Here is, however, what he wrote, the very year of his death, from Goëttingue to Van Mons, one of his friends:—

"Since I made the discovery that oxygen will cure venereal diseases, that is to say, for twelve years, I have made a large number of experiments, and here you have what I have found out: When a disease is not incurable, and when it only requires the first degree of oxidation, I employ citric acid; for the second degree, diluted oxalic acid; for the third, and in general for the most inveterate cases, a solution of the oxide of arsenic. I do not know of anything better for venereal diseases, liver affections, obstructions of the abdomen, dropsies, etc.; but it is essential that the lungs be not attacked, otherwise the patient will perish in a short time. I mix four or five drops of a solution of the white oxide of arsenic [in nitric acid] with two pounds of water, and I order this to be taken in two days. I have performed some wonders with this remedy. Nothing is more efficacious in intermittent fevers. If, however, the patient begins to cough, the remedy must be stopped, since the dry cough indicates that the body begins to be superoxygenated. If the cough continues, one can make it cease in a little time by the use of sulphur. I will tell you later of an experiment repeated more than one hundred times."

Unfortunately, his administration of oxygen was but an imitation of Fourcroy.

At Geneva, which has always advanced to the front rank in the army of progress, pneumatic therapeutics was a most brilliant success. Jurine, although not having obtained very remarkable results, greatly promoted the efforts made with the gases, and Odier, who about that time was one of the most reputable physicians in Geneva, employed them in his practice, when the publications of Beddoes appeared. "Considerations on the Factitious Airs" was analyzed in the British Library, with

* Berlin, 1792, 8vo.

the most extensive detail, and was estimated as of the highest importance. Odier more than ever encouraged this new medication; even more, the Society for the Advancement of the Arts and Sciences was induced to supply the physicians of the country the means of administering it, and instructed a committee to prepare extensively all the apparatus necessary for the preparation and employment of the gases.* The practice gained this, *i.e.*, the thorough perfecting of apparatus by Watt. The Genevese engineer had the idea of preparing oxygen water, that is to say, water which under the influence of strong compression holds in suspension its volume of oxygen. This artificial gaseous water, which has none of the characteristics of hydrogen binoxide (peroxide) discovered later by Thenard, was for the Genevese physicians a very useful adjuvant in the treatment by oxygen, and even in some cases of mild form, in which they did not wish to have recourse to the gas, oxygenated water frequently sufficed to dissipate the disease.

7. Oxygen in the Nineteenth Century.—In leaving this period it may be said that oxygen had been almost completely abandoned. Condemned to disuse by nearly all the authors who had had occasion to speak of it more or less directly, even by Pereira,† it was scarcely possible that oxygen should any longer be received in the domain of current therapeutics, and if in our time recourse has been had to this gas, it has been only under the head of remedies of last resort that it has been employed. Thus, in 1832 several distinguished physicians attempted to administer the gas in the last stages of cholera, but without success. This was necessarily the case, since in the stage of collapse [asphyxique] there is no longer present the phenomenon of absorption, and consequently oxygen cannot act. And yet none were then inclined to revert to this agent, although Broughton and Dutrochet had just aroused the attention of the medical public to oxygen, by some contributions which were, however, quite unimportant.

For some years following, oxygen seems to have regained a degree of favor with our cousins on the other side of the Channel. Thus, within fifteen years, there have appeared in England several works treating on the medical use of this gas, without counting the isolated reports published in the journals.

* British Library, chapter vii.

† Elements of Ther. and Mater. Med., 3d ed.

For some time there has been a veritable revival of the success obtained by the aid of this fluid in all parts of the world—at Philadelphia, at New York, at Calcutta, and even at Rio Janeiro. We are constrained to add that, while the example of Beddoes has been an encouragement to these recent *revivalists*, the immense progress communicated to physiological chemistry by Gmelin, Berzélius, Dumas, and especially by Liebig,* has contributed most toward this resurrection of oxygen as a remedial agent. It is chiefly to Liebig that belongs the honor of having set forth, with a clearness and lucidity wholly French, the chemical phenomena of the living organism, of showing from this the principal rôle played by oxygen in the complicated act of nutrition, and of having thus demonstrated, chemically and physiologically, all the good effects which might be derived from such an agent, wisely managed. Thus, in the publications of which we have yet to speak, we shall find at almost every step his ideas and his theories. Finally, in the pages which are to follow we can scarcely fail to equally recognize the influence of this author, since, had we not been guided by his teachings, we certainly should not have dared to face the difficulties of a subject but slightly chemical, decidedly physiological, and scarcely at all surgical.

The work of Riadore † has little interest for us, since, concerning oxygen, he reports scarcely any but cases and theories previously published. Beddoes, Hill, and Liebig furnished him all that he reported in his book concerning the gas we are studying. He speaks, it is true, of his personal experiences, and of the excellent results he had obtained; but he quotes barely one or two cases of which the details were personally known to him.

The work of Birch‡ announced an extensive experience in the employment of oxygen. It presents us a very complete study of the physiologic action of this gas, the rôle it plays in the regular performance of all the functions, and of all the divers troubles which appear to follow the insufficient absorption of the gas by the organism; then the author explains the prophylaxis of certain affections of the digestive canal through the aid of inhalations of oxygen, and he concludes by reporting a dozen

* Organic Chemistry Applied to Physiology and Pathology, 1839; Letters on Chemistry, 1843; New Letters on Chemistry, 1852.

† On the Remedial Influence of Oxygen, Nitrous Oxide, etc., etc. London, 1853.

‡ On the Therapeutic Action of Oxygen, etc. London, 1857.

cases of quite diverse character, selected from his practice and treated with success by this means. We shall take the liberty of borrowing from him some observations for the purpose of corroborating those which we may have to present.

We will not quote, but barely mention, the brochure which an enterprising manufacturer * published, in 1859, on the therapeutic use of oxygen, with a special view to popularize a method of preparing and administering the gas by the aid of an apparatus of his invention, which, for that matter, seemed to be sufficiently ingenious, but which has since been greatly improved, as we shall demonstrate, in treating the subject, later on.

In France, for some years, the curative properties of vital air have been freshly brought back to notice by M. Haten, and more especially by M. de La Passe; but their meagre experience did not permit these authors to authentically establish their therapeutic points.

Finally, the favorable results produced by compressed air, it seems to us, reinstate oxygen, to some extent. The remarkable effects obtained by Junod, Bertin, and especially by the illustrious Lyonese physician, Dr. Pravaz, must be chiefly attributed to oxygen. In every instance, in fact, Pravaz, in his remarkable work on compressed air, interposes oxygen as a powerful modifier of the organism. This gas evidently penetrates in greater quantity into the circulating fluid in an individual inclosed in a receiver of compressed air than in the same individual when under the open sky. Far be it from me to deny the influence of compression itself. It certainly plays a great rôle; but in our opinion, after attentively reading the work of the Lyonese physician, the great influence of compressed air is evidently derived from a more extensive absorption of oxygen. Every reader will be convinced of this by studying with care the physiological effects of vital air, and comparing them with those of compressed air.

The summary of this prolonged historical dissertation is this:—

Of all these efforts very little was permanent. Must we, therefore, admit that all these authorities, who have recognized and proved the good effects of the inhalation of oxygen on themselves as well as on others, have allowed themselves to be led into error? However ephemeral may have been the success

* George Fath. London, 1859.

realized, attributable, no doubt, to a lack of more thorough and more considerate perseverance, it is none the less evident to us, in spite of the neglect into which the remedy has fallen, that it possesses, in a therapeutic point of view, resources almost infinite, and a potency the most efficient. Is it necessary to let them sleep their eternal sleep, under the pretext that their results have often failed of positiveness and accuracy? Now that the science of diagnosis and of pathological anatomy have made such progress, ought we to neglect a method of treatment at once so easy and so energetic? We believe that we should at least attempt to examine anew all the facts, some of which are almost marvelous, and see if there is not in this agent a valuable aid to the healing art. Sensible persons shall decide whether we have ourselves been deceived.

II. PHYSIOLOGICAL ACTION OF OXYGEN.

We have just seen, by an examination of the principal works touching the medical history of oxygen, how much the study of the physiological properties of this gas leaves to be desired. Some points of the subject have been treated separately, and in a more or less complete manner; but no work comprehending the whole subject has yet been presented. Now, before we would apply oxygen to therapeutics we must make sure that it is assimilable; or, rather, whether by causing to be breathed an artificial atmosphere, more highly charged with oxygen than common air, it is possible to fix in the animal organism an appreciably greater proportion of this gas than is found to be absorbed during normal respiration.

Since, then, we are going to treat of the physiological action of oxygen, it is necessary, first, to particularize that we have not here an ordinary pharmaceutic substance, endowed with a special therapeutic virtue. We are in the presence of the vivifying element, *par excellence*, the element without which organic metamorphosis, the *circulus vital*, as they say to-day, in Germany, is impossible. Atmospheric air may, in short, be considered as a solution of oxygen, of which nitrogen is simply the vehicle. Atmospheric nitrogen is not, however, limited to this rôle in the organism. We shall see, on the contrary, further on, that it serves another purpose; but this is at least its most apparent function. We conclude, then. that if oxygen is mingled with another gas endowed with almost nega-

tive properties, it is because nature intended to modify thus the too active effects of the former. It follows that this state of dilution is ordinarily sufficient for the perfect support of life.

A thought, however, very naturally suggests itself to the mind, as to whether it is not feasible, in certain cases in which it would seem desirable, to favor or accelerate the processes of assimilation and disassimilation [constructive and destructive metamorphosis] of which oxygen is the prime promoter. This contingency having been admitted, is it possible to reach this result by increasing the quantity of oxygen which each inspiration throws into the circulating current? Some say yes, others say no. Count Morrozzo, Spallanzani, and Sennebier, Allen, and Pepys hold to the affirmative; however, their experiments were not sufficiently conclusive, and are even considered defective by MM. Regnault and Rieset, who assert a contrary opinion. But the experiments of these last authorities, are they exempt from all criticism? For example, are we to believe that it is a matter of indifference that we compel an animal to remain motionless in a receiver during a longer or shorter period, in order to discover whether it exhales more carbonic acid when supplied with an unusual quantity of oxygen? It does not exhale more carbonic acid solely because it is motionless. It is just at the moment when the animal is removed from the receiver, saturated with oxygen, and placed at liberty, that we should measure the quantity of carbonic acid exhaled, and we shall then find that it is really more considerable than in the normal condition. Numerous experiments prove, in fact, that we are thus enabled to accumulate oxygen in the organism, to a certain extent, and that this superabundance finally passes off, after a certain interval, involving an increased production of carbonic acid. Moreover, if we cause the animals thus superoxygenated to perish, we find, at the autopsies, positive proofs of the accumulation of oxygen.

Hence it is at this point that we note an important gap in the otherwise so remarkable labors of MM. Regnault and Rieset.

Furthermore, our everyday experience teaches us that it is possible to thus superoxygenize the system, and this result is reached, indirectly, by a number of methods. Exercise of all kinds, fresh air, compressed air,—all these effect this result in a more or less perfect manner. But since their mode of action is susceptible of being interpreted very differently, direct experi-

mentation is absolutely indispensable in order to fully establish this fact, already partially demonstrated. Besides, the whole question of therapeutic oxygen is involved in this inquiry; this is, in a measure, the key to the arch. Therefore we will proceed to submit, with details, the experiments we have made in connection with this subject.

1. General Considerations.—Impressed with the importance of bringing into bold relief this point, that *we can cause the organism to absorb more oxygen than it receives through normal respiration*, and at the same time for the purpose of better studying physiological phenomena which we have in some degree developed, we have caused animals which were suffering from wounds to respire oxygen, sometimes pure and sometimes mixed with a certain proportion of air or of carbonic acid; have injected the same gas into the serous membranes, the cellular tissue, and into the veins; have placed animals in an atmosphere composed exclusively of this gas; and finally, following so many others, have studied the action of vital air on the healthy man, as well as on individuals afflicted with either recent or chronic wounds. Witness, then, for the sake of greater precision, the following series of experiments. In case of dogs, we have made in the axillary region a large wound involving the skin, the cellular tissue, and the pectoralis major muscle. These deep incisions, at the end of four or five days, were covered with granulations. Then the animal was caused to inhale an atmosphere of oxygen, either pure or mixed with a certain proportion of common air. In a very short time, as is proved by the following experiments, carefully conducted under our personal observation, by two pupils of the service, MM. Lavaysse and Meric, both of whom were as earnest as they were intelligent, we observed a very remarkable vascularization of the whole wound, and at the same time noted a profuse serous discharge from the abraded surface. If the experiment was prolonged minute ecchymoses were produced, as though the whole wound had been pricked with fine points, or stimulated. Usually, after these experiments, the animals were lively, and after a short time the wound recovered its normal aspect. These experiments do not leave any doubt in the mind. Oxygen unquestionably enters in greater quantity into the circulating fluid when it is respired pure, or mixed with but little air. The efflorescence of the wound, the serous exudation, and the minute

ecchymoses abundantly prove this. But this physiological fact ought to be supplemented by a chemical analysis, which we are not prepared to perform. It is a question of determining the quantity of oxygen contained in the arterial blood of a dog in a normal state, and of subsequently finding out, after inhalations of oxygen, the increased quantity of this gas which the blood can contain. This experiment, under other conditions very simple, will surely be made by some chemist, if, as we hope, oxygen shall in future take high rank in medical therapeutics.

First Experiment.—Respiration for seven minutes of a mixture of equal parts of air and oxygen. Ecchymotic patches; abundant serous exudation.

June 3d, at five minutes past ten o'clock, a terrier dog, having an ulcer with gray edges and slightly rosy centre, was caused to breathe a mixture of air and oxygen. Two minutes after this superoxygenated respiration was established the wound became generally rosy. At the surface bright ecchymotic spots appeared which subsequently gave rise to slight hæmorrhage. Serum flowed profusely from the whole extent of the wound. As soon as the hood, which covered the dog's head, was removed, and at the first inspirations of free air, the wound immediately changed its aspect. To the red tint succeeded a gray color, and the surface, lately possessed of a fine polish, became pale and dry. One would liken it to a mirror on which one had breathed.

Second Experiment.—Respiration of oxygen for six minutes by a terrier dog which had an open wound at the level of the axilla. Bright efflorescence of the wound; profuse flow of serum.

The wound of this animal was three days old; it was but faintly red; a very thin film of serum moistened its surface.

The experiment began at ten minutes after ten, May 17th. Two minutes after the dog began to breathe oxygen the wound showed a change. Little red points were at once perceived at the surface, resembling the markings noticed on the surface of the brain when the pia mater is removed. These red points spread over the surface, and soon gave place to a slight hæmorrhage. An abundant serous effusion occurred over the whole extent of the wound.

The respiration was slightly accelerated and the pulsation of the heart was more rapid than in the normal state. At the

end of the experiment (ten o'clock and twenty minutes) the general condition of the dog was most satisfactory; the edges of the wound were dry.

Third Experiment.—Respiration of pure oxygen for twelve minutes—opening of the femoral vein. No modification in the color of the venous blood; the temperature remains the same.

On the 6th of June, at thirty-eight minutes past ten o'clock, the femoral vessels of a dog of medium size were laid bare, and a mercurial thermometer placed in the rectum, the temperature being $39\frac{1}{10}°$ C. At the same time the dog was made to breathe pure oxygen by means of an ordinary hood. The femoral vein was opened; the blood which escaped was of a deep black, nor was its color changed even at the end of the experiment (ten o'clock and fifty minutes).

The dog made some deep inspirations, but did not display any movement indicating uneasiness.

Throughout the experiment the thermometer fluctuated between $39\frac{1}{10}°$ and $39\frac{2}{10}°$ C.

Fourth Experiment.—Respiration of pure oxygen for thirteen minutes. Hæmorrhage; no elevation of temperature.

The dog in this experiment had, five days previously, received two wounds,—one in the axilla, the other in the groin. His temperature was $39\frac{3}{10}°$ C.

On the 10th of June, at seven minutes past ten, he was caused to breathe pure oxygen. At the end of two or three minutes the two wounds assumed an intense red color, and exuded considerable serum. On their surfaces little points could be discerned, red at first and afterward becoming slightly hæmorrhagic. At the end of the experiment the temperature indicated by the thermometer was practically the same as at the commencement. The general condition of the dog was very satisfactory.

It follows from these experiments that oxygen which we cause to be respired by animals, whether in a pure state or mixed with a certain proportion of common air, produces invariably, in these wounds, the same phenomena, namely:—

1. A much greater injection of the capillaries, which coalesce to form granulating surfaces.

2. Increased exudation of serum and plastic lymph.

3. Lastly, the formation of bloody points, eventuating in minute ecchymoses. A fact not less interesting, which may

be deduced from these experiments, is that the venous blood does not undergo, during the operation, any modification in color. Moreover, the temperature has not been sensibly changed. We have recovered the gas expired after the inhalation of pure oxygen, and have determined that it is composed of unusual quantities of oxygen and carbonic acid, the relative proportions of which were not determined.

The foregoing experiments seem to us extremely important in a therapeutic point of view, since they demonstrate in a positive manner that the blood can be superoxygenated, and that vital air exercises a positive action on the tissues. For surgery this is a most important fact, of which we shall recognize the great utility when we treat of the influence which vital air exercises on atonic ulcers of an unhealthy nature.

The phenomena observed in case of these animals have likewise explained to us why it was that the consumptives treated by Chaptal, at first much pleased with the action of oxygen, later on found their condition aggravated, especially if it was thought to make them breathe oxygen continuously for a considerable time.*

In these cases the pulmonary cavities of these unfortunate patients certainly became the centre of more active processes, following which were bloody expectorations and fever; and, in addition to the phenomena which we have demonstrated in connection with wounds produced in animals, we have found the same in ulcers of diseased people whom we have subjected to the use of oxygen.

2. Injection of Oxygen into the Cellular Tissue and Serous Membranes.—Oxygen may be injected into the cellular tissue, and also into the serous membranes of animals, with perfect impunity. The results of our first attempts, made with the co-operation of M. Lecompte, were reported in 1859 in the *Archives Génerales de Médecine.* In that paper we not only demonstrated the harmlessness of injections of oxygen gas, but we also studied the laws of their absorption.

Oxygen brought into contact with the tissues is rapidly absorbed, since in about two hours and a half after the injection but very faint traces of the mixture can be recovered, whether

* Our author seems to have, for the moment, forgotten how impure was the gas used by Chaptal. Between free chlorine and mercurial vapors it is not at all strange that the results were disastrous.—Trans.

the operation is performed during a fast or during active digestion; but its absorption seems to be arrested at times, at least as compared with the exhalation of other gases. Hence it is that frequently, in the same series of experiments, we find, at the second termination, a much greater quantity of oxygen than at a first trial. In the cellular tissue during fasting, for example, after about forty-five minutes, an analysis gave 66.66 per cent. of [absorbed?] oxygen; and at the end of an hour it showed 78.35. In the peritoneum, also during fasting, in about forty-five minutes, there was found 77.65, and at the end of an hour 81.86 of oxygen.

The same as with common air, the animals have not appeared to suffer from oxygen injections, the results of which disappear with remarkable rapidity.

The idea of studying the action of oxygen injected into the cellular tissue occurred also to Beddoes, and here is an experiment reported by him:—

"We injected under the skin of a dog four pints of oxygen. During the first hour there was slight uneasiness, and afterward the animal seemed to experience an excess of vital activity. The day following the gas began to disappear. Toward the end of the tenth day all the gas appeared to have been absorbed. In case of another dog, weighing nineteen pounds, three pints of the gas was absorbed in eight days. In case of a third, weighing twenty-one pounds, three pints was absorbed in eight days. In a fourth, of twenty pounds, three pints in seven days. The second and third animals were slightly affected, the same as the first, but the fourth experienced no unpleasant effect."

3. Prolonged Immersion of an Animal in Oxygen.—We already know, through the medium of facts demonstrated by science and confirmed by our own experiments, that animals can live in an atmosphere of pure oxygen without harm and for a longer time than in a like volume of common air. But beyond a certain limit the animals succumb, and then we assure ourselves that the medium which they have been respiring is still capable of rekindling an ignited body,—quite evident proof that death takes place in the presence of oxygen itself, and not by the changes which occur through its mixture with carbonic acid exhaled.

[This inference is evidently hasty and incorrect. Richardson's experiments clearly show that pure oxygen inhaled by

warm-blooded animals, the unabsorbed portion of it recovered, purified and proved by chemical test to be pure oxygen, is no longer capable of sustaining warm-blooded animal life. Cold-blooded animals will, however, survive in it for a short time. This makes it evident that even pure oxygen may exist in a devitalized—perhaps *non-magnetic*—condition, and perhaps accounts for the differences observed between compressed oxygen and the same gas at normal tension, as, also, between stale or long-evolved and fresh or *nascent* gas. Clinical experience leads me to assert that stale, as well as compressed, oxygen is in a certain degree devitalized. Hence, it is easy to account for the negative results frequently reported. This point is more fully considered in another part of this work.—TRANS.]

In this respect all our experiments correspond with those of Broughton,* but they differ in other respects.

A word concerning apparatus. We caused to be constructed, by M. Galante, a large cylinder of vulcanized rubber. This apparatus was of the capacity of about one hundred and twenty-five litres, and had on two of its sides glass plates, which permitted a study of the movements of the animals. Two conducting tubes, of quite different capacity, were attached to the two sides of the instrument. One of these tubes, the lesser one, communicated with an iron retort containing five hundred grammes of chlorate of potash, mixed in a certain proportion with fine sand. This retort, placed on a glowing furnace, soon disengaged oxygen, which was conducted into the apparatus, after having been washed in milk-of-lime. The other conducting tube, very much larger, permitted the introduction of the animals on which we desired to experiment. We have now described the apparatus, and here we have the results of our experiments:—

As soon as the animals on which we proposed to experiment were placed in the apparatus, in order to drive out the atmospheric air, the washed oxygen disengaged by the retort was introduced. When the apparatus was entirely filled (with oxygen) the greater part of the gas was permitted to escape, and was replaced by fresh. In this manner our animals were immersed in oxygen mixed with but a very slight quantity of air. The animals on which we experimented were hens, pigeons, and rabbits.

* Experimental Researches on the Physiological Effects of Oxygen and Other Gases on the Animal Economy (Arch. Géner. de Méd., 1st series, t. xxiii, 1830).

Fifth Experiment.—On the 6th of August, 1863, at half-past eight in the morning, I placed under experiment two robust and active rabbits. One of these rabbits remained in the apparatus an hour and three-quarters, after which it was killed. The other remained in the apparatus, and died at the end of fourteen hours. When the animal was removed from the apparatus it was ascertained that the atmosphere in which it had been immersed was still capable of rekindling ignited bodies [supporting combustion].

The two rabbits placed in the apparatus were lively. They moved about with spirit, but soon after became restless, and ended by being covered with perspiration. The animal which survived fourteen hours was quite damp. Both these rabbits manifested intense thirst, eagerly licking the drops of water which condensed on the glass sides of the apparatus.

Let us note the necroscopic results. In order to estimate more accurately the effect of oxygen on the animals used in the experiment, we also killed a healthy and well-conditioned rabbit, and were thus enabled to compare the viscera as well as the muscles of the last animal with those of the animals used in the experiment. Every one is familiar with the pale flesh of the rabbit and its want of vascularity. The internal organs, as the trachea, the mesentery, the alimentary canal, are all normally only moderately vascular.

Autopsy of the rabbit which had been kept an hour and three-quarters in an atmosphere of oxygen:—

The muscles had a rosy color; the intercostal, the abdominal, and the lumbar muscles, in particular, were all redder than normal. It appears that this red color is inherent in the muscular fibre itself, and is not due to the injection of the veins. After twenty-four hours the flesh was still redder and firmer. Blood taken from the venæ cavæ and the jugulars retained the properties of venous blood, and coagulated rapidly. Exposed to the air it assumed a lively, brilliant color. The small intestine and the mesentery were very vascular and of a decided red. One could trace the delicate arborescent ramifications, and could invariably distinguish veins from arteries. The kidneys and liver were hyperæmic, but of all the organs the lungs and trachea were most vascular. On section of the lungs, in thin slices, arterial blood escaped. The nerve-centres presented nothing in particular, except a slight injection of their substance.

Autopsy of the rabbit dead after being confined in oxygen for fourteen hours:—

The lungs were of a bright red, and upon incision arterial blood escaped. The small intestine was also of a distinct red, as though its vessels had been injected with vermilion. The vessels of the mesentery were very prominent. By its transparency we could see a very great increase of vascularization. The kidneys and loins appeared also more vascular, especially the kidneys. The heart was a more intense red. The vessels which ramify over its surfaces could be distinguished much more readily than in case of the two other rabbits. The right heart contained black clots, which distended its cavities. We compared the flesh of the last rabbit with that of the first. It was quite distinctly different in point of coloration: pale in one, very bright in the other. The autopsy was made twelve hours after death.

We deemed it necessary to repeat these experiments, because of the remarkable contrasts which they present to those of Broughton. In substance, this author says, in his eleventh conclusion: "In animals which have respired oxygen for a certain time, arterial blood circulates in all the vessels, the entire mass of this liquid presenting, in fact, the brilliant red of arterial blood."

In order to verify this fact, which was in opposition to our former experiments, we made two new ones.

Sixth Experiment.—We inclosed a pigeon, a hen, and a rabbit in our apparatus, filled with oxygen. At the end of one hour and forty-five minutes' confinement we killed these animals. It was evident, at this time, in case of the hen and the pigeon, that there was a decided injection of the muscular system, and especially of the thorax. The trunk veins of the neck and the inferior vena cava were examined, and it was noted that the blood from these vessels retained its usual dark tint.

Seventh Experiment.—We inclosed two rabbits in our apparatus, charged, as in every case, with oxygen. At half-past nine o'clock we gave these animals some carrots to allay thirst. After a little time their respiration became very rapid, and finally panting. The rabbits hopped about in a lively and disorderly manner. They shook themselves, and licked the bars attached to the sides of the cage. After eight hours' confinement in oxygen one of them was removed and killed. When taken from

the apparatus it was found to be covered with perspiration, quite feeble, and somewhat stupid; but its restoration to the free air for a few minutes revived it.

Autopsy: The muscles, especially of the thorax, were of a decidedly florid color, instead of the usual dull white. Blood drawn from the jugular veins and from the venæ cavæ was light purple, and coagulated slowly. The veins and arteries were perfectly distinct. The liver, the kidneys, the intestinal tube, especially the small intestine, were exceedingly vascular. The heart also contained red and liquid blood. The lungs were intensely red; the blood oozing from them was a bright arterial red. The larynx and trachea were much injected. On examining the intercartilaginous rings we discovered a fine exudation of mucus.

The second rabbit lived sixteen hours in the atmosphere of oxygen. We verified the fact that at the moment when the animal was removed the gas which had served during the experiment would still rekindle flame in an ignited body. We found in this case, as in the preceding ones, a vascular engorgement and very remarkable development of the entire venous and arterial systems. This was the most prominent point in these experiments. It seemed as if the blood mass had been singularly augmented. The veins were uniformly more prominent and distinct than the arteries, and presented a purple appearance. The venous blood appeared to us a little less dark. It reddened very quickly, as in the preceding experiments, on exposure to the air, and remained fluid for a long time.

Our experiments, as any one can readily see, differ from those of Broughton, in this, that however long our animals remained under experiment, the venous and arterial blood preserved their usual distinct characteristics. But, as observed by Broughton, and even before him by Beddoes, the organs of animals which have respired oxygen are generally quite vascular and turgescent. One peculiarity on which Beddoes insisted, but which we have not verified, is the patches of inflammation, and the gangrene of the lungs, or rather, more properly, if the description of the condition of superoxygenated animals is carefully examined, it would be found that the English author obtained the same crude results as we have done, but that he has merely interpreted them in a different manner; that is to say, he thought he found inflammation and

gangrene, where he had only congestion and some sanguineous effusion.

"A cat was placed in a receiver that contained eighty per cent. of oxygen, and was permitted to breathe it for seventeen hours, after which it was killed, together with another cat which had breathed under normal conditions.

"The lungs of the oxygenated cat were of a fine red color; of the other they were pale. The contrast was most striking, whether they were insufflated or not. *In the first, the edge of one lobe was marked with little livid patches, similar to those observed in gangrene. The pleura was found in a state of quite manifest inflammation.* The heart was a bright vermilion. The liver, the kidneys, the spleen, the blood-vessels of the mesentery and of the bladder were of a pronounced red color. In the other cat, on the contrary, the heart was of a dark color. The liver, the kidneys, the spleen, and the blood-vessels in general had a bluish or purplish color. These cats were killed by being immersed in water.

"In the case of the first cat the heart promptly responded to stimulation applied to it. The spontaneous contractions of the auricles and ventricles were rapid, and they persisted, with slight diminution in frequency and force, for more than half an hour. At the end of an hour they had entirely ceased.

"In the other the irritability of the heart was from the first doubtful. On opening the pericardium, nearly half an hour after the removal of the sternum, the movements of the heart became very apparent, and they persisted for more than an hour after the opening of the thorax.

"In another series of experiments we caused a rabbit to breathe, for fifteen minutes, in a mixture of three parts oxygen and one part common air, and killed it at the same time with another rabbit of the same size. In the oxygenated rabbit, neither the vena cava nor the blood contained in it appeared redder than in the normal state; but the blood of the oxygenated rabbit coagulated more rapidly, and the liver was also of a darker color than usual.

"Two rabbits of equal size were likewise killed in our presence. One of the two had been kept for a quarter of an hour in an atmosphere of pure oxygen. In this particular case neither the veins nor the blood were positively redder than in the normal

condition. Coagulation, however, was, as in the former experiment, more rapid, and the clot was firmer.

"On the borders of the lung of the oxygenated rabbit we noted red patches analogous to those which had appeared in animals a long time confined in oxygen, and which I had believed to be points of inflammation. The right auricle and ventricle presented evidences of a much more decided irritability, as did also the diaphragm and intercostal muscles." *

It may be objected that in our experiments the animals which succumbed after fourteen or sixteen hours' confinement in oxygen were dead from changes that the new atmosphere in which they had been placed had undergone, by the exhalation of carbonic acid. To this we reply, first, that augmentation, apparent or real, of the blood mass existed also in a very marked degree, in animals which we killed after a confinement of an hour and forty-five minutes in an atmosphere of oxygen, or after several hours, and in these latter cases the carbonic acid seemed to have had a marked effect; second, that the air in which our rabbits died was still capable of re-igniting burning bodies, which proves that it had been but little modified. It would have cleared up this question could we have analyzed the remaining gases; and happily this has since been done by men who are competent in such matters,—MM. Regnault and Rieset.

We quote what these eminent men say: † "We have never observed that animals experienced the least uneasiness in these atmospheres very rich in oxygen. Their respiration does not appear to be in the least embarrassed even at the end. The receiver, in fact, contained more oxygen at the end of the experiment than ordinary air contains; and the great quantity of carbonic acid which accumulated did not seem to produce untoward effects. The animals removed from the receiver have been in good condition, and soon regained their complete functions."

Further on (page 402) they add: "The presence of the small quantity of carbonic acid did not in any manner interfere with respiration, since we assured ourselves that animals may remain for a long time, without manifesting any uneasiness, in an atmosphere containing more than one-half its volume of carbonic acid, provided this atmosphere contains a sufficient pro-

* Beddoes' Consid., etc., 3d ed., part i, p. 14 *et. seq.*

† Chemical Researches on the Respiration of Animals of Various Kinds (Annales de Chim. et de Phys., xxvi, p. 399, 1849).

portion of oxygen." [It will be noticed that in all the experiments of our author no account is taken of the presence of deadly *ptomaines* in these closed receivers. It is the presence of these subtle agents that proves fatal, not the absence of oxygen nor the presence of carbonic acid.—TRANS.]

Finally, in order to determine the action of oxygen on the organism, and its entrance into the blood in greater quantity, Beddoes made a series of very ingenious experiments which we will report in full. The reasoning of the English physician is as follows: If oxygen enters in greater quantity into the circulation, since it is the element which supports life, it follows that an animal which has respired it for some time will better resist the tendency to death from asphyxia than one which has not respired it. Experiment has completely confirmed this.

Eighth Experiment.—"Two kittens, which we will designate C and D, in like condition, of the same size, and apparently of the same vigor, were plunged into water at the same instant, and were kept there until they had lost consciousness, and were completely asphyxiated. C had previously been confined for twenty minutes in a mixture of two parts pure oxygen, derived from manganese, and one-third atmospheric air. Care had been taken to introduce into the receiver from time to time a fresh portion of oxygen, so that the contained air should be constantly more highly oxygenated than common air. This we made sure of by plunging into it a lighted taper, of which the flame, in consequence of this excess of oxygen, became much more fierce and brilliant. D had breathed only atmospheric air. On removing them from the water we could still perceive in both a slight movement of the lower jaw. At the end of a minute and a half C arose and began to walk, at first totteringly, but very soon as well as usual. The apparent death of D continued much longer. It lasted fifteen minutes, at the end of which time the animal arose, but soon tumbled over again and actually died the next day. C was, on the contrary, full of life and health."

This experiment was repeated many times, and always with a similar result, no matter how diverse the circumstances. When the animals which had been overcome were both fully recovered we reversed the experiment, oxygenating the one that had not been. The results were always the same. The oxygenated animal, whichever it was, always showed the most vitality.

Its movements in the water were more lively; it lost consciousness more tardily, and recovered much more surely and more promptly.

Ninth Experiment.—"Two dogs, E and F, were drowned, not in water, but in hydrogen or inflammable air, which, being a non-respirable fluid, causes the death of an animal plunged into it, the same as water. E had been previously superoxygenated, during ten minutes, in a mixture of two parts pure oxygen and one part common air. F had not been so prepared. F was at first very much excited. At the end of five minutes he lay on his side scarcely breathing. At the end of twelve minutes he did not breathe at all. E was perfectly quiet from the start, lying on his belly, head between his paws, and muzzle resting on the bottom of the vessel. From the first moment he breathed only rarely, and during the last six minutes he did not breathe at all. He was believed to be dead, but scarcely had he been removed from the receiver when he began to cry, shook himself, soon walked, and completely recovered. F on the contrary was dead; and neither by the heat to which we exposed him by placing him before the fire, nor by a current of oxygen which we directed to his mouth, nor by any other means could we restore him to life.

"Two other dogs of a similar condition, G and H, after having respired for the same length of time, in two separate receivers, a mixture of two-thirds atmospheric air, with, for G, one-third oxygen, and for H, one-third hydrogen, were both at the same instant plunged into tepid water until both were asphyxiated. G appeared to be but slightly affected and soon revived. H, on the contrary, remained for a long time without movement. Oxygen, which we caused him to breathe, had a marked effect in connection with his resuscitation.

"In this connection, can we not deduce an important lesson from this experiment, with reference to the resuscitation of drowned persons? And, since oxygen can be kept intact several months or even years in well-stoppered receivers, should we not, in places designated to supply help to drowned persons, always keep on hand several flasks (or cylinders) of it to restore respiration?"

We have just seen that animals which have been caused to breathe oxygen better resist asphyxiation than those which have not breathed it. But observe another experiment, quite as

interesting as those cited. Beddoes desired to know whether animals which had inhaled oxygen could better resist the action of cold than those which had not inhaled it. In order to determine this fact he inclosed a rabbit which had not breathed oxygen in an apparatus surrounded by a refrigerating mixture. Another rabbit, which had breathed oxygen for a given time, was placed in a similar condition. Now, the one which had breathed oxygen survived the experiment, while the other one quickly succumbed. This experiment is also more interesting because it proves the influence of oxygen upon vital resistance, notwithstanding the fact that the animal temperature was not at all increased during these tests.

Two very positive facts are deducible from these experiments:—

a. The apparent increase of the volume of the blood under the influence of oxygen inhalations. Whoever will repeat the same experiments we have made with rabbits will be struck by the exaggerated development which the sanguinary element seems to undergo in the animal experimented on, compared with another animal killed for purposes of comparison. To explain this fact, which equally impressed Beddoes, it is absolutely necessary to admit that there are in the blood histogenetic elements. These elements are, in all probability, the white corpuscles of the blood, or leucocytes, which are in a state of transition into red corpuscles. Whatever explanation may be given of this fact, it exists, and the first time we demonstrated it it forcibly impressed us.

b. The second fact, which is but a sequence of the first, is the exaggerated vascular development in the muscles, observed in rabbits and birds on which we experimented. It serves more and more as an experimental corroboration of that discovery of Lavoisier, to wit, that under the influence of muscular contractions the absorption of oxygen may be more than doubled during the act of respiration. The muscles, in fact, appropriate a large quantity of oxygen, as we have already shown.

4. Injection of Oxygen into the Venous System.—We have indulged in a large number of experiments for the sake of determining the influence of oxygen introduced directly into the circulation. Our experiments have been particularly directed to the venous system, and, after the example of Nysten,

who observed the utmost thoroughness in his investigations, we became convinced that it was possible, by injecting small quantities of the gas at a time, to cause a considerable quantity of oxygen to enter into the circulating current without causing serious trouble to the functions. The pulsations of the heart became more frequent, as occurs when small quantities of common air are injected. But if, instead of introducing small quantities of oxygen at a time, we inject it quite suddenly, or if the quantity be increased, the animal cries out, rolls over, and at the same time there occurs a relaxation of the sphincters, and death follows, as when we inject too great a quantity of air. In these cases there was found dilatation of the right cavities of the heart, which were filled with a bright-red bloody froth. If we trace this froth through the branches of the pulmonary artery it is found for some distance, but very soon after reaching the last bronchial branches we find nothing of it. There is then, in these cases, a two-fold cause of death: 1st. The distention of the right cavities of the heart, as clearly seen by Nysten, and on which Amussat so strongly insists. 2d. The impossibility of this blood-froth passing through the pulmonary artery, a phenomenon more particularly pointed out by M. Mercier. Air, like oxygen, then, in these experiments, kills only mechanically, not chemically. In making these investigations, we wished to determine to what extent it was possible to resuscitate animals, stunned in any manner, by a prompt injection of oxygen or air. The results of our experiments were the same with oxygen and with air; that is to say, every time we injected moderate quantities of oxygen at a time, we could overcome the accident, either by the aid of electric currents, or preferably by inducing artificial respiration by alternate pressure upon the abdominal and the thoracic walls. By thus arousing the phenomena of life, time is given to the blood to dissolve to some extent the excess of oxygen which may be introduced into the heart. To accomplish this result, it is necessary that the heart shall not be distended by too large a quantity of vital air, without which precaution death is inevitable and nothing can avert it. Nysten concluded from these experiments that oxygen, aside from its physical influence on the heart, had no effect on the arterial blood,—no more, we add, than on the venous blood, as we propose to demonstrate.

But did this establish the fact that vital air, introduced into

the circulation, has no action on the organism, and that nothing can prove its presence?

Since wounds act as a mirror in which the disorders of the system are reflected with sufficient fidelity, we thought they would serve us in studying the influence which oxygen exercises on the capillary circulation, and in understanding the nature of the office this agent is required to perform in the organism.

It is evidently in the capillary circulation that the intricate phenomena of nutrition are accomplished. Now, if we can avail ourselves of the transition of vital air in the course of the capillary vessels which form the "proud flesh" of a wound, it will be possible for us to comprehend the rôle which oxygen plays in the economy when it is introduced into the circulation, even although the venous system which has received it, has not, under the eye of the observer, undergone any appreciable modification.

This we have observed in dogs on which we have produced open wounds. We injected, slowly, by the jugular vein, a certain quantity of oxygen, using very small quantities at a time, in order to give the blood time to absorb it. Each injection was followed by an interval of rest long enough to permit the animal to recover from the momentary agitation caused by the operation. It goes without saying that the quantity should be proportionate to the vigor of the animal. After a certain number of injections we saw the wound redden, a serous exudation appeared, and minute petechiæ were apparent on the surface of the ulcer. This fact we have shown to be very important in a physiological and practical point of view, since it demonstrates that oxygen, thus injected with due precaution into the venous blood, remains wholly or partly fixed in the circulatory system, and that it is not rejected, immediately, by the act of respiration. We shall see, further on, to what extent we have further investigated in animals the point in question.

In injecting a definite quantity of oxygen into the jugular, or into the crural vein, we have been struck by one thing: it is that the venous blood, to the extent that it has not been mixed in the right cavities of the heart, does not change its color in the least. We have thought this was due to the small quantity of oxygen which we injected. In order to more carefully investigate this point we injected a large quantity of oxygen, either through the inferior vena cava, reaching it below the liver, or

through the portal vein, and we have found that no matter what quantity we injected we could not make the venous blood lose its character; and that the latter could absorb very large quantities of vital air without interfering with the functions of the heart or causing death.

But the capital fact of these experiments, in a therapeutic point of view, is that a small quantity of oxygen introduced into the circulation makes a sensible impression on a wound or ulcer in case of any animal under experiment.

Tenth Experiment.—Injection of oxygen into the jugular. Death in forty-five seconds; blood from the right heart and pulmonary artery red and frothy.

May 25th, at thirty-one minutes past ten o'clock, oxygen was injected into the jugular vein of a dog of medium size, having an ulcer. During the first thirty seconds the dog presented no abnormal symptoms. Fifteen seconds later a gurgling noise was heard, resulting from the mingling of gas and blood, and almost immediately the animal uttered a plaintive cry, his respiration became embarrassed, and he died. No change was apparent in the vicinity of the wound.

Autopsy: Contraction of the auricles.

The right auricle and right ventricle, the pulmonary artery and its immediate branches were flushed with red and foaming blood. At the level of the right auriculo-ventricular orifice, and on the tricuspid valve, we found a fibrinous clot of inconsiderable density. Electricity caused energetic contractions in the involuntary muscles. The heart was insensible to this stimulant.

Eleventh Experiment.—Injection of eighty cubic centimetres of oxygen through the jugular. Ecchymoses and an exudation of serous fluid from the surface of the ulcer; asphyxiation, and a return to life, through artificial respiration. Duration of the experiments, fifteen minutes.

The dog under experiment was of medium size. He had, opposite the axilla, a wound three days old.

May 29th, at fifteen minutes past ten o'clock, we injected oxygen into the jugular vein. At the end of three minutes the animal was uneasy and uttered cries. At the same time there was heard in the precordial region a peculiar chopping sound. The respiration was labored, the sounds of the heart abrupt; the stop-cock was turned off. At the end of two minutes, more

gas was injected. At this moment the ear, applied to the precordial region, perceived a distant blowing sound which resembled, so to speak, the sound of a turning lathe in motion.

The wound assumed an intensely red color; its surface was etched with ecchymotic points and covered with an abundant serous exudation.

We continued the injection of oxygen, but after a few moments the dog fell as if struck by lightning. However, we succeeded in resuscitating him, after practicing artificial respiration (ten o'clock and thirty minutes).

Twelfth Experiment.—Injection of oxygen into the jugular of a dog which had an ulcer at the level of the axilla. Ecchymotic spots; serous exudation on the surface of the wound.

The 14th of May, at ten minutes past ten, we injected oxygen into the jugular vein of a terrier dog, of good size, having a livid and palish ulcer at the level of the pectoralis major.

The wound changed appearance at the end of ten minutes. It became rosy; some reddish points appeared upon its surface; granulations became more apparent, and a perceptible quantity of serous fluid exuded from all parts of it. During the first four minutes respiration was regular, then it became profound and labored. The stop-cock was now turned off.

After a minute and a half of interruption, communication was re-established between the jugular and the oxygen reservoir. Soon the wound became a brilliant red, and on its surface little ecchymotic patches appeared. During this second part of the experiment the dog showed neither agitation nor restlessness.

The experiment ended at twenty minutes past ten o'clock. It had lasted, therefore, twelve minutes.

Thirteenth Experiment.—Injection of two hundred cubic centimetres of oxygen by the crural vein. Death.

Autopsy: Blood in the right auricle a vermilion red.

The 22d of June, at twenty minutes past ten, we injected by the crural vein one hundred and fifty cubic centimetres of oxygen at two separate operations, with an interval of five minutes. Heart sounds very frequent.

At thirty-four minutes past ten, fifty cubic centimetres of the same gas. Respiration accelerated. The dog uttered a cry and died.

Immediate autopsy. The right auricle contracted, showing

by transmitted light a vermilion-red color. The anterior jugular was opened and a large quantity of gas escaped, mixed with some fluid; nevertheless, it is questioned whether the gas had traversed the entire circulation, and whether the animal did not die from interference with the heart. Impelled by this idea, we opened the brain and found marked congestion, no gas. It is allowable, therefore, to assume that the gas found in the jugular had regurgitated into this vein, under the influence of the contraction of the auricle.

The right auricle was found distended by gas. Not a single bubble of gas was found in the left auricle, or in the aorta.

The liver and kidneys presented, on section, fluid blood, mixed with a considerable quantity of gas.

Fourteenth Experiment.—Injection, within thirty minutes, of nine hundred and twenty-one cubic centimetres of oxygen by the portal vein. No cardiac symptoms.

The 17th of June, at twenty-five minutes past ten, we opened the right side of a medium-sized dog and exposed the portal vein. We injected, through this vein, at ten different operations, with an interval of three minutes between, nine hundred and twenty-one cubic centimetres of oxygen.

During the entire experiment the dog showed no uneasiness. On auscultation we discovered an intense blowing sound, resembling the noise of a locomotive.

At fifty-four minutes past ten we opened both sides of the thorax. The heart was seen to beat in an irregular and jerky manner. We made a final injection into the portal vein (the animal still living), and the noise of the arrival of the gas in the heart was heard at some distance. The dog was not quite dead; the eye still retained slight sensibility. Some minutes later the animal succumbed.

Autopsy the following day. Upon making an incision into the liver a frothy and quite fluid blood freely exuded. We found no gas in the inferior vena cava nor in the right auricle, which contained very dark blood.

Fifteenth Experiment.—Injection, within forty-five minutes, of eighteen hundred cubic centimetres by the portal vein. Intense redness of the spleen. Injection of the intestinal capillaries. Frothy blood in the abdominal aorta.

The 23d of June, at a quarter past ten, we injected, at twelve operations, observing four-minute intervals, one hundred

and fifty cubic centimetres of oxygen through the portal vein of a dog of small size. The animal bore the injections without disturbance.

The spleen presented an intensely red color. When crushed between the fingers a distinct crepitation was perceived. The intestines were intensely injected, even to their remotest capillary branches. Suggillations between the folds of the omentum.

The veins were brown in color, and contained some gas, which was seen to traverse their walls. Opening one of these veins, fluid and frothy blood escaped.

At the end of the experiment (eleven hours) we opened the chest and the dog succumbed, almost instantly. The abdominal aorta was opened, and from it frothy blood escaped; which proves that the gas had traversed the pulmonary circulation without having been completely exhaled through the pulmonary surface.

Sixteenth Experiment.—Introduction of six hundred cubic centimetres of oxygen by the inferior vena cava. Injection of all the intestinal capillaries. Death.

June 20th, at a quarter past ten, by means of a syringe of the capacity of one hundred and fifty cubic centimetres, we injected oxygen gas through the inferior vena cava, in case of a vigorous dog of good size. At the instant of making the injection the ear was applied to the chest-walls and detected the peculiar blowing sound resulting from the mingling of gas and blood.

During this experiment we could detect strange phenomena on the part of the intestinal circulation. All the capillaries were injected. All the little vessels situated between the folds of the omentum and on the convex surface of the intestine formed a beautiful plexus, closely knitted together. At the same time suggillations could be seen between the layers of the omentum. All the capillaries were of the color of arterial blood. The last injection having been forced in without interruption, and, so to speak, at a single stroke, the pulsation of the heart, at first very rapid, was suddenly suspended. Respiration became anxious, then profound and infrequent, and the dog succumbed. Instantly the thoracic cavity was opened, showing contractions of the right auricle; those of the right ventricle could hardly be perceived. The vena cava below the heart was

distended by gas to at least five or six centimetres; the blood of the right auricle was brilliant red; lungs intensely red.

A fact which struck us, and to which we recall attention in concluding this chapter, was the scarlet-red coloration which the spleen assumed, on injecting oxygen by the portal vein, while all the other viscera retained their normal color. This experiment deserves to be repeated, since by studying the condition of the blood which circulates in the spleen both before and after the experiment, perhaps a corner of the veil could be raised which prevents us from discovering the functions of that organ. The splenic organ was not only injected, but had become firm, voluminous, and greatly distended. *These experiments* [apparently —TRANS.] *demonstrate that the spleen is a creative organ for the blood-corpuscles, and that the latter await, in some manner, merely a final contact with oxygen in order to complete their evolution.* On the other hand, if we take account of the exaggerated vascularization presented by the abdominal viscera, when penetrated by a current of oxygen, we shall readily reach the conclusion that oxygen not only vivifies the blood-globules, at the same time inducing the exhalation of carbonic acid, but that, more than this, carried to the heart of the organism, it stimulates the development or organization of the various elements which should co-operate in the formation of the blood-globules. The exaggerated development of vascularization in all the viscera proves that the creative or reparative elements of blood are everywhere present, and that in the spleen they reach the most advanced stage of their evolution, since *there the blood can assume its vermilion color without having previously undergone the influence of passage through the lungs.*

[The italics are mine.—TRANS.]

5. PHYSIOLOGICAL EFFECTS OF OXYGEN BY INHALATION.— When we re-read what Priestley, Ingen-Housz, Beddoes, and so many others have written upon the effects produced by oxygen respired in a state of health, we have reason to be astonished, not only that it should have been abandoned as a curative means, but that it should have been treated as a dangerous gas, because of its activity in chemical combustion. It is true that the prevailing theory upon pulmonary chemical phenomena, such as Lavoisier assumed, have contributed not a little toward giving to oxygen its incendiary reputation. Not that, under certain

circumstances, for example, in the presence of a tendency to an inflammatory state, this gas may not give rise to accidents. In fact, later on, we will suggest contra-indications for the employment of oxygen. But if one really desires to get the opinion of the authors above cited, to all those who have, either voluntarily or upon our advice, prescribed, or themselves respired this gas; if, in short, our personal experience can add any weight to this affirmation, one will be convinced of the harmlessness of oxygen respired intelligently, in reasonable doses. This fact is very important, since this gas has, therefore, this advantage over a majority of therapeutic agents,—that it can be used, with such discretion, without any danger of serious accidents; and since, in our opinion, it is destined to render important service, this is certainly a very remarkable property, and one which it is important to note.

When one can breathe with impunity fifteen to thirty litres of oxygen, we cannot understand the apprehensions concerning it, expressed by various chemists and physiologists. Not only have we many times repeatedly respired this quantity without the least inconvenience, but our friends, Drs. Foley and St. Vel, have followed our example. The pupils, already named, and others have alike inhaled this agent without experiencing any but transient phenomena. We have already caused a large number of invalids to inhale oxygen. Not one of them who has been subjected to the action of this vital air, within the limit of ten to thirty litres, has experienced the slightest inconvenience. We dwell on this fact in order to reassure persons who are timorous with regard to new agents.

We will describe the usual phenomena produced by oxygen, forewarning the reader that all individuals do not experience the same impressions. There are even some who experience little or no sensation. This evidently depends upon the idiosyncrasy of the subjects and their state of health. To proceed more systematically, we will study the action of vital air, taking each function by itself. This done, we will give the particular sensations of numerous persons who have studied the action of this agent in a thorough and circumstantial manner.

The first inhalations of oxygen sometimes occasion a slight sensation of warmth in the mouth, which extends to the larynx and the interior of the chest,—a sensation more agreeable than otherwise; at least, this is what we have experienced. Beddoes

claimed to have experienced a burning sensation in the chest,—a phenomenon complained of by no other that we know of, to that degree. This warmth diffuses itself throughout the hypogastrium, but disappears in a few moments after one ceases to inhale the oxygen. Nor must we at any time forget that this sensation may be wanting, or it may be intensified by a morbid condition of the respiratory passages. This follows from facts observed by physicians of the last century, who had at times inconsiderately administered this gas in the treatment of phthisis. The pulse at the moment of the entrance of vital air usually rises.* The pulsations may increase from four to twenty and upward, and also become more firm; but this phenomenon does not last long. In some cases the pulse does not increase in frequency, or even undergoes a slight diminution; but the phenomenon which has been observed as most constant is the firmness of the pulse-beat. Many experience, during the inhalation of vital air, a sensation of warmth of the skin and a tendency to perspiration. The effects upon the senses, as regards the central nervous system, are scarcely noticeable. One may be occasionally slightly intoxicated, and nervous persons experience a sensation of tingling at the finger-ends, and of slight agitation; others a feeling of gayety; while others feel a very remarkable necessity for muscular activity. This we have ourselves observed in several experiments, and at the same time a sort of constriction in the temporal region. Certain subjects have complained of more or less acute pains in the course of various branches of the trifacial nerve, such as the supraorbital, the infraorbital, and the temporal.

On the part of the digestive functions we would call attention to a very important and quite general fact,—the development of the appetite. The majority of invalids, to whom we have administered this agent, have almost all experienced, at the end of a few days, this need of reparation, as indicated by the appetite. This is an important point, since it indicates what is being accomplished in the heart of an organism of which the blood has been better oxygenated,—a phenomenon accompanying reconstructive metamorphosis. Beddoes, and all those who, like him, have employed oxygen, have been struck by this

* A long and varied experience does not corroborate this assertion. Although the effect on the pulse varies to some extent, oxygen almost invariably slows and decidedly strengthens a weak and unnaturally rapid one.—Trans.

remarkable influence on the digestive function ; but minds wholly occupied with the treatment of phthisis have not sufficiently comprehended what conclusion should be drawn from this invaluable action of oxygen toward the reconstruction of an enfeebled organism. Caillens, however, one of the first to prescribe vital air in phthisis, very clearly saw that *it is but by restoring the vital energies that this gas acts as a curative means.*

Pravaz, in his remarkable work on compressed air, insisted in every case on the reconstructive action of this agent. But if we reflect that whatever is employed with a subject may seem to be dominant in its influence, it will be easy to understand that, in the complex effect produced by compressed air, oxygen is the active and reconstructive agent, *par excellence.* As bearing on this point we cannot too highly recommend the reading of the remarkable work of the Lyonese physician.

We have sought to discover the influence of oxygen as regards other functions of the economy, especially as to the secretions. In this direction nothing important has impressed us. In this kind of experiments it is necessary to guard against those nervous natures possessing a lively imagination, and more or less avidity for that which is marvelous; also against those who answer affirmatively every question which is addressed to them on this subject. Again, to avoid errors with patients as much as possible, we have concealed the name of the agent, and especially the end sought. In regard to the action of oxygen on morbid phenomena, that is a question which we will study later on.

Upon the whole, oxygen respired in proper proportions manifests, in some way, properties essential and special toward the subject under experiment. We have just given, in a general way, the sensations experienced by us, and by invalids subjected to the action of vital air. Here we have, in addition, what M. de La Passe, who has studied the effects of oxygen on himself, reports :—

"In 1843, the author of this work demonstrated, by experiments on himself, that a person can live many hours in an atmosphere strongly saturated with oxygen, without experiencing any other symptoms than a vast increase of vitality; and he has succeeded in relieving himself of an atrocious migraine by the frequent use of oxygen inhalations. Numerous others,

suffering from neuralgia and chronic affections of the respiratory passages, have been relieved and finally cured by the same means."*

Further on (page 143) the author adds:—

"Acceleration of the pulse follows, at the rate of about ten pulsations per minute. This symptom persists for nearly an hour after the experiment. Acceleration of the digestive function and astonishingly marked increase in the appetite; general sensation of strength and well-being, and quite characteristic freedom in the respiratory function."

Still further on (page 151) he says:—

"If, during the heat of July or August, you confine yourself, as did the author of this work, at Naples, in a little room or closet, hermetically sealed, you will experience a sensation of oppression and insupportable prostration; you will be bathed in perspiration; you will smother. Introduce then a current of oxygen, mixed with balsamic vapors; inhale large whiffs of the gas; let the excess of it diffuse itself in the apartment, and at once you will breathe freely, perspiration will be arrested, and you will experience a general sensation of vigor and well-being. You will even be able to remain many hours in this little apartment, provided you have taken care to place beside you a vessel containing lime and potash, to absorb the carbonic acid contained in your emanations. You will emerge from this sweating-room, fresh, hearty, and with an excellent appetite, and the ensuing night you will sleep a profound and peaceful sleep."

We have just noted, without any preconceived theory, the phenomena observed by persons who have breathed vital air. It is important, at this point, to compare these same effects with those of compressed air. Yet, in making this comparison, it will be necessary to set aside the physical phenomena produced by compressed air. The latter, in fact, may prove competent to play an important rôle in medico-chirurgical therapeutics. But it is evident that the most important phenomena which we are called upon to notice in the action of compressed air are the chemical, as well as the physiological, phenomena. These are especially the phenomena which we wish to revert to in order to compare them with those which follow the respiration of oxygen. Note how Pravaz expresses himself in his work (page 102):—

* Essai sur la Conservation de la Vie, par M. de La Passe, p. 141. Paris, 1856.

"This is the place to call attention to the contrast presented by the appetences and the needs of the economy as regards the alimentary regimen when a man respires in a rarified atmosphere, as that of high mountain regions, or in a very dense atmosphere, like that of a diving-bell. If, in the first case, the appetite is wanting, if azotized substances or spirituous liquors are rejected with disgust and become prejudicial, in the second the consumption of food is not only more considerable, but also the aliments must be selected from those which contain, in a given bulk, more nitrogen and more carbon. Under the diving-bell the workmen do not perform more difficult labors than workmen who operate in free air. It is not, therefore, the great outlay of strength which induces the extreme exhaustion of which they complain after remaining some hours in compressed air; but, the absorption of oxygen being far greater, tissue metamorphosis becomes much more rapid. It is to restore a part of the excessive waste caused by this acceleration that divers need to consume more nitrogen in their food than they have been accustomed to select (eggs, flesh, fish, tea, etc.); and, in addition, in order to check the too rapid progress of destructive metamorphosis, they have instinctively had recourse to the use of substances which Liebig has classified under the name of respiratory food (beer, alcohol). Therapeutic induction should utilize the foregoing physiological observation; and we will show, in fact, further on, what a fertile source hygiene and organoplasty can find in the activity which compressed air imparts to the process of organic renovation."

A little before Pravaz, M. Junod, in his memoir addressed to the Academy of Science, had already said:—

"Whenever the normal pressure of the atmosphere is increased one-half, the following phenomena are observed:—

"The tympanic membrane, forced toward the inner ear, becomes the seat of an uncomfortable pressure, which is finally dissipated, little by little, in proportion as the equilibrium is re-established, probably by the passage of condensed air into the drum of the ear by way of the Eustachian tube. The act of respiration is accomplished with novel ease; the capacity of the lungs for air appears to be increased; the inspirations are deep and less frequent than in an ordinary state. At the end of fifteen minutes an agreeable warmth is felt in the interior of the chest. The circulation shows modification; the pulse is frequent, full, and

readily compressible; the calibre of the superficial vessels diminishes, and is even almost completely obliterated, so that the blood, in its return to the heart, seeks the course of the deep-seated veins. The intellectual functions are aroused; the imagination is brilliant; the thoughts are associated with a peculiar charm, and in some cases there is a sort of delirium, or intoxication. The muscular system participates in this increase of activity; the movements are easy, energetic, and seem more positive; the processes of digestion and of the secretions, especially that of the salivary glands and the urinary organs, are freely performed. One would say that the weight of the body had diminished in a perceptible manner; at least, such is the sensation experienced by a person inclosed in a compressed-air apparatus."

After the example of Pravaz, we ought to be competent to offer some criticism as to the assertions in the description above set forth, but it illustrates the sensations experienced by the author, and we leave them, so that the reader may be able to compare them with the phenomena reported by those who have respired vital air.

But whether it is a fact which proves the identity of effect, under certain conditions, between the action of vital air and that of compressed air, this is certainly the observation of Dr. Michet,* as follows:—

"The derangement of the stomach, of which I have been cured by the air-bath, was the result of the prolonged use of opium in large doses. I had had recourse to this drug for the purpose of relieving obstinate rheumatic pains. In order to sustain the effect the dose had been gradually increased, and had reached as much as four grains of acetate of morphia per day. My pains having yielded to appropriate treatment, I suspended the use of opium very abruptly. An enfeeblement resulted, involving all the organs. The muscular forces remained as if exhausted; the bowels performed their function very badly; they were in some degree paralyzed. But the organ most diseased was the stomach. Anorexia was complete; there existed even a veritable repugnance to all sorts of food. That which I forced myself to take remained like lead in the epigastric region. The tongue was white and thickened, the mouth was clammy and dry. For fifteen days I had taken no morphine, and the

*Pravaz, *op. cit.*, p. 322, 323.

conditions remained unchanged. The appetite did not return; feebleness remained the same. At this time I began to use compressed-air baths, of twenty minutes' duration each, at a pressure of half an atmosphere. From the first I experienced a sensation of hunger, of moderate degree, and later on this feeling increased to such a pitch of intensity that it delayed me to be taken out of the bath to be placed at the table; and during the repast it was only by an effort of my reason that I could eat with moderation, or refrain from overloading my stomach, of which the strength was not in proportion to my appetite. Nine baths sufficed to re-establish the digestive organs in the fullness of their functions, and to inaugurate a return of strength which was not fully realized until much later."

But, after having compared our own sensations, under the influence of oxygen, with those of the authors quoted above, who have reported the phenomena experienced in compressed air, instead of adding to the quotations taken from these authors, we have asked our friend, Dr. Foley,—who has published a very remarkable work on the effects of compressed air, and who at our invitation very much desired to respire oxygen,—to state in what way the sensations imparted by oxygen resembled those which are experienced in compressed air. Now, the response of Mr. Foley is very positive. We here give a summary of it, since it seems to us of a character to forcibly impress the mind of the reader:—

"I do not hesitate to affirm that the inhalation of pure oxygen produces upon us many of the effects of compressed air.

"These effects are, at first, superhæmatosis of the blood; the latter, in turn, arouses, in active people, muscular impatience, as does compressed air; in cheerful people an excess of joy; in sleepers an increase of sleepiness; in almost all an increase of appetite, as always occurs with compressed air.

"Outside of physiological limits does the same parallel obtain? Yes.

"With the brain fatigued by study, the hand cramped by too much writing, the various lines of the face troubled by one cause or another, inhale oxygen, and (just as if you had been in compressed air) you will experience heaviness of the head and tingling at the ends of the fingers; only you will suffer a hundred times less.

"Let us note the pathological facts:—

"Here we have an injured man suffering from a livid and unhealthy ulcer, and another patient with purulent urine. We superoxygenate both of them, and immediately the urine of this one is improved, and the wound of that one reddens. On the other hand, there is a man whom work in the vacuum tubes [caissons?] has exhausted. He does not breathe; the conjunctivæ are purple; his lips blue; his skin pale, dirty, leaden. He is as thoroughly stupefied as if he were typhoid. Compress the air to two or three atmospheres, and you will soon see him become quite fresh and vigorous. Is it not evidently the same thing?

"The superhæmatosis from inspiring pure oxygen and that which compressed air produces resemble each other in more than one particular.

"The direct absorption of the hæmapoietic blood, can it replace the compression of air, and is it worth more or less?

"In order to reply to these questions let us admit (what experimentation only can prove) that the inspiration of oxygen sufficiently prolonged can redden the blood to the same degree as increased pressure. Admitting this, in what cases should oxygen be prescribed and in what excluded?

"In every case in which, the *primæ viæ* being free, you wish to superoxygenate the organism, inhalation will be more valuable than compression, since you will spare the patient excruciating pains.

"But when the nares, the glottis, or the bronchiæ are obstructed by œdema, or when there are false membranes or fungous growths, recourse must be had to compressed air.

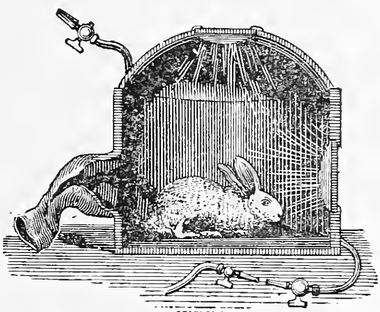
"And this is also true in case of persons who, on account of age or disease, are no longer able to breathe under ordinary barometric pressures.

"Whenever, in superhæmatizing your subject, you desire to preserve the integrity of the sensations and the elements of innervation, or even to increase the latter, the inspiration of the pure gas is preferable. But if, on the contrary, together with a greater purity of the blood, you wish to cause less excitement in the system, compressed air will be preferable.

"Therefore, while admitting for the moment that the virus of rabies can be modified by a superoxygenation of the blood, in view of the nervous phenomena, I would, in hydrophobia, a thousand times prefer compressed air to the gas.

"In case of purulent infection or adynamic blood-poisoning, oxygen, in my opinion, would be worth more."

If, in a chemical and physiological point of view, there is a similarity of action between compressed air and oxygen, it remains to be seen whether, from a therapeutic stand-point, the analogy remains the same. This we shall demonstate, by and by, when setting forth all the aid that therapeutics can derive from inspiration of vital air,—fortunate if we shall succeed in attracting the attention of physicians to one of the great resources of therapeutics. The Lyonese remedy, under the impulse and suggestion of Pravaz, includes all the good effects which can be expected from the employment of compressed air, even as demonstrated by the labors of this learned physician. Thus, we expect, by demonstrating that in many cases oxygen effectually replaces compressed air, to attract the attention of physicians who are not prejudiced in advance concerning an agent as marvelous as it is powerful in its action.



CAGE FOR INCLOSING ANIMALS FOR EXPERIMENT.

CHAPTER III.

Of the Preparation and Administration of Oxygen.

I. PREPARATION AND PURIFICATION OF THE GAS.

The question of the production of oxygen has for a long time engaged the attention of chemists; but it has been less from the stand-point of its medical use than from that of its industrial applications that they have directed their efforts.

From the first attempts toward the introduction of oxygen into therapeutics, the importance of using none but perfectly purified gas has been recognized, and it is also evident that in many cases in which its use has been followed by disturbances which have caused it to be discontinued, it has been its impurity to which this result should have been attributed.

In these first attempts, about 1789, they made the grand mistake of employing for the preparation of a gas destined to be administered to invalids, the binoxide of mercury, or red precipitate, this being the substance which had led Lavoisier to his fortunate discovery of the composition of atmospheric air. The employment of this substance in the preparation of gas for medical use ought to have been strictly prohibited. We find, nevertheless, the admission of Chaptal on this subject, as also an account of the three experiments performed by him, in the "Annales de Chimie"*: "I have uniformly observed that the use of oxygen gas, evolved from the mercuric oxides, produces salivation, at the end of a few days' use. I cannot doubt, after this observation, but that it holds in a state of solution [sublimation] some traces of mercury, and I was convinced of this fact by the following experiments:—

"*First Experiment.*—I placed some red precipitate in a retort and arranged the hydro-pneumatic apparatus so as to evolve and collect the gas. I applied promptly a strong flame to drive it over and obtained it in a vaporized form. I uncorked the flasks containing it and exposed them to the air. After a little time I found their sides obscured by a deposit of gray

* T. iv, p. 23.

powder. Some days later, having detached and analyzed this powder, I recognized it as being oxide of mercury.

"*Second Experiment.*—Some flasks filled with oxygen gas, produced from red precipitate by the usual process, exposed to a temperature of 15° below zero for four hours, deposited on the sides a film of mercuric oxide which I was able to estimate at *one-third of a grain* per pint of gas.

"MONTPELLIER, 1st September, 1789."

The methods used, or proposed to-day, for the preparation of oxygen gas are numerous. We will examine successively the seven principal ones:—

1. Decomposition of peroxide of manganese.
2. Decomposition of chloride of lime.
3. Process of Boussingault.
4. Decomposition of sulphuric acid, or of the sulphates, by heat.
5. Reaction of sulphuric acid on bichromate of potassium.
6. Bouchardat's process.
7. Decomposition of chlorate of potassium.

1. DECOMPOSITION OF PEROXIDE OF MANGANESE.—By this process oxygen is easily obtained, whether we treat the peroxide by heat only, or whether we combine this agent with sulphuric acid. But in the first instance a very high temperature is required, and in the second, the use of an agent, unpleasant to handle, and always impure, as found in the market. The gas thus obtained requires thorough washings, which render the operation tedious. It contains, also, 4 to 5 per cent. of nitrogen, which comes from the decomposition of the nitrates contained in the manganese.

The value of peroxide of manganese, as regards its yield of oxygen, varies considerably, according to its source. At times its yield is almost nothing, because it has been mixed with earthy matters in large proportions. It is also sometimes adulterated with charcoal dust. An English pharmacist, in preparing oxygen from the peroxide of manganese, was severely wounded by the explosion of the retort in which it was being manipulated, a pupil who assisted him being killed by the accident. An analysis of the peroxide used by them showed that it contained a considerable quantity of charcoal, which, by its rapid combustion in the gas, had caused the explosion.

The peroxide of manganese sometimes contains, also, organic materials which cause the formation of dangerous detonating mixtures when it is desired to test the presence of oxygen gas by applying a lighted taper to the outlet-pipe.

2. Decomposition of Chloride of Calcium.—By heating to a dull red the hypochloride of calcium with a little slaked lime, forty to fifty litres of oxygen per kilogram can be realized. This process has the drawback of producing also some chlorine, which necessitates washing through several alkaline solutions, and the yield is comparatively inconsiderable.

3. Process of Boussingault.—The process of M. Boussingault, which consists in obtaining oxygen from barytes, by utilizing the property which it has of absorbing the oxygen of the air, at an elevated temperature, and of yielding it again at a higher temperature, gave rise to the hope of being able to prepare oxygen very economically. But, unfortunately, the results obtained in practice have not corresponded with what was promised by this very fine theory. It results from the experiments of MM. Deville and Debray that the operation requires the intervention of a current of moist air, which is, in many respects, hard to conveniently manage, since as soon as the humidity of the air exceeds a certain degree a pasty mass of hydrate of baryta results, and the operation becomes extremely difficult to conduct. It is necessary, in addition, that baryta shall be free from fusible material, nitrates and nitrites.

All these disadvantages, together with that of the necessity of employing a very high temperature, have prevented this ingenious process from receiving, as yet, any practical or industrial application.*

4. Decomposition of Sulphuric Acid, or of Sulphate of Zinc by Heat.—For these two processes, which we join in one, since in both cases oxygen is evolved by the decomposition of sulphuric acid, we are indebted to MM. St. Claire Deville and Debray, who have also proposed to make an economic industrial application of it to the metallurgy of certain bodies.

Their process depended upon the property, possessed by sulphuric acid, of decomposing, under heat, into sulphurous acid

* This process has been recently made more feasible by means of an apparatus, the invention of the Messrs. Brin Freres, of Paris. It requires, however, the employment of an extensive and costly plant; and the gas realized is variable in quality, containing, it is said, from 5 to 40 per cent. of atmospheric nitrogen, which, if not strictly an impurity, is at least a troublesome diluent.—Trans.

and oxygen; and that of sulphate of zinc, decomposing, at bright-red heat, into oxide of zinc, sulphurous acid, and oxygen.

It was thought probable that, by this entirely new process, the industrial production of oxygen would soon be a solved problem; but, unfortunately, with respect to obtaining this gas for medical uses, we shall have to dismiss it. It requires us to have recourse, at once, to an agent disagreeable to handle—sulphuric acid—and also to employ, in its preparation, platinum apparatus, which enormously increases the cost of the product. We must add to this the trouble of thoroughly washing gas obtained from any such source.

To this process we may connect that which consists of decomposing plaster, or sulphate of lime, by heat, in the presence of silica or argillaceous matter, a process of which the first conception was due, it is said, to M. Fremy; but which, as is seen, closely imitates the foregoing, since it is in each instance the decomposition of sulphuric acid which affords the oxygen.

5. Reaction of Sulphuric Acid on Bichromate of Potassium.—Dr. Richardson, at a recent meeting of the British Medical Association, stated that by this process, due to Mr. Robbins, we can produce oxygen as readily and as abundantly as we now obtain hydrogen by the reaction of sulphuric acid on zinc; and that by means of it the patient can himself prepare his own gas, and inhale it.

No statement could be more misleading, for the reason that bichromate of potassium yields but 16 per cent. of oxygen, since it is produced as a result of this reaction from chrome alum. A person unskilled in chemistry cannot handle sulphuric acid with impunity, nor can he conveniently regulate the heat necessary to the operation; besides, the inhaling arrangement is faulty, for the reason that the gas cannot be regulated as to dosage, since it must be respired, virtually and in fact, as fast as it is disengaged. The same authority also suggests treating the binoxide of barium with sulphuric acid; but, as this salt is formed from the sulphate of the protoxide of barium, we cannot, to advantage, secure all the oxygen, and the employment of this substance cannot be seriously considered on account of its commercial value, which is in the neighborhood of sixty francs per kilogram.

6. M. Bouchardat, in his *Therapeutic Annual* for 1865, gives a method for preparing oxygen, which he has employed

for a long time, in glycosuria, in many cases of suffocation, and in the uric acid diathesis. This process consists in gradually pouring upon a mixture of equal parts of peroxide of barium and peroxide of manganese rectified pyroligneous acid (*acetique du bois*).

The apparatus, which is very simple, consists in a large flask with three necks. To the first is connected an S-shaped tube, which serves to introduce, from time to time, acetic acid; to the second a safety-tube; to the third we connect, through the intervention of a glass tube, a small wash-bottle of water. The wash-bottle is fitted with an India-rubber tube, furnished with a mouth-piece, which serves for the inhalation of oxygen gas.

This apparatus, as is seen, has the same objection as that of Dr. Richardson, since it is impossible to know what dose of the gas one respires. Moreover, we cannot produce it in sufficient quantity, nor rapidly enough, to enable us to administer to a patient twenty to thirty litres in a few minutes, as it is necessary to do in common practice. By this method it is equally impossible to effect a mixture of the gas with air, in desired proportions, as is necessary to do in some cases, especially at the beginning of treatment.

7. Decomposition of Chlorate of Potassium.—When we decompose chlorate of potassium by heat we obtain chloride of potassium and oxygen, $KO\ CLO^5 = KCL + O^6$ (now written $KCLO^3 = KCL + O^3$.—Trans.). Chlorate of potassium is evidently the substance which most readily yields the whole of its oxygen. The gas thus obtained is almost pure, and the operation is easily conducted. It is with gas obtained from chlorate of potassium that all our experiments have been made.*

The following is the mode of preparation, to which M. Leconte has resorted since we began the administration of this gas at the City Hospital: In an iron retort is placed one kilogram of chlorate of potassium mixed with one kilogram of fine, dry sand. It is heated on an illuminating-gas furnace, and the

* Oxygen produced by electrolysis of one or another of its compounds, although successfully accomplished in the laboratory, has not yet been made a commercial success. Considering the immense strides of progress recently made in electro-chemistry, it is not unreasonable to predict that all our present processes for evolving the gas will at an early day be superseded by better and more economic ones.—Trans.

oxygen is passed through a washing-bottle or flask containing milk-of-lime. This flask is connected with a demijohn, having a capacity of sixty litres, nearly full of water. In its mouth or neck two tubes are fitted. The tube which conducts the gas is a little longer than the neck; the second projects nearly to the bottom.

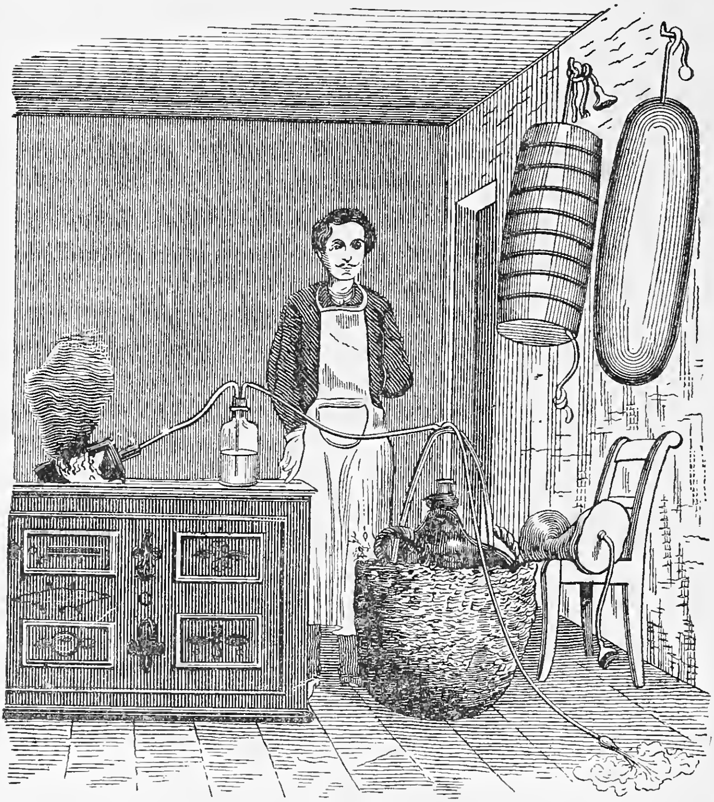


FIG. 1.—OXYGEN GENERATOR. ORIGINAL FORM, WITH RECEIVERS AND DISPENSING BALLOON.

The influx of gas forces the water to escape by the second tube. When all the liquid is displaced, and the demijohn consequently full of gas, to cause it to flow out, water is to be introduced through the tube which reaches to the bottom, and the other tube is connected with a rubber balloon, or with an inhaling apparatus.

M. Limousin, a pharmacist, who has given much attention

to this preparation, since pneumatic medicine has been popularized in Paris, has constructed an ingenious and convenient apparatus for preparing oxygen in large quantities from chlorate of potassium, and also for administering it. This apparatus has the advantage of being easily and economically arranged in any drug-store or pharmacy. The following is a description of the process as he gave it in the *Journal des Connaissances Médicales*, the *Bulletin de Thérapeutique*, and the *Union Médicale* :—

"We take one kilogram of very dry chlorate of potassium, which we place in an iron retort of the capacity of three or four litres, and provided with a neck or collar of large calibre, into which is adjusted, through a cork stopper, a glass tube, connected by a rubber tube with a wash-bottle, having a capacity of about four litres, and very thick walls. This washing-flask contains milk-of-lime, which should fill it to about one-third of its capacity.

"Oxygen gas, liberated from the chlorate of potassium, is washed in this lime solution, and passes into a reservoir having a capacity of about two hundred and fifty litres, and which has been previously filled with water. A strong cask, in good condition, will answer this purpose perfectly. By means of two corks we insert into it two tubes, one of which projects nearly to the bottom, and the other is level with the surface of the liquid.

"The gas arriving by the second tube, which communicates with the washing-jar by a rubber connection, communicates its pressure to the liquid contained in the receiver, and forces it to rise in the tube, which is joined exteriorly by a rubber connection long enough to raise the water into a second receiver placed above the first, and having the same capacity. All the water displaced by the gas passes into the upper reservoir, and the flow does not cease until the completion of the operation.

"At the lower part of the second reservoir is fixed a tube, graduated into two hundred and fifty equal parts, corresponding with its capacity of two hundred and fifty litres, and communicating with the interior. By this means we can accurately follow the progress of the operation during the preparation of oxygen, and can determine, by the descent of the liquid in the tube, how much gas is transferred into a balloon, or any other receptacle which we wish to inflate, as we shall see further on.

"To obtain a uniform decomposition of chlorate of potassium, and at the same time to avoid the use of a safety-tube, I decompose the salt by means of illuminating gas. The retort is placed on a gas-furnace, surrounded by the casing of an ordinary furnace, and covered by a dome. By this arrangement all absorption [dissipation of heat?] becomes impossible; hence, the temperature will not fluctuate, and we secure a very uniform disengagement. It is necessary, however, to take pains to lessen the heat a little, at the instant when the decomposition of per-

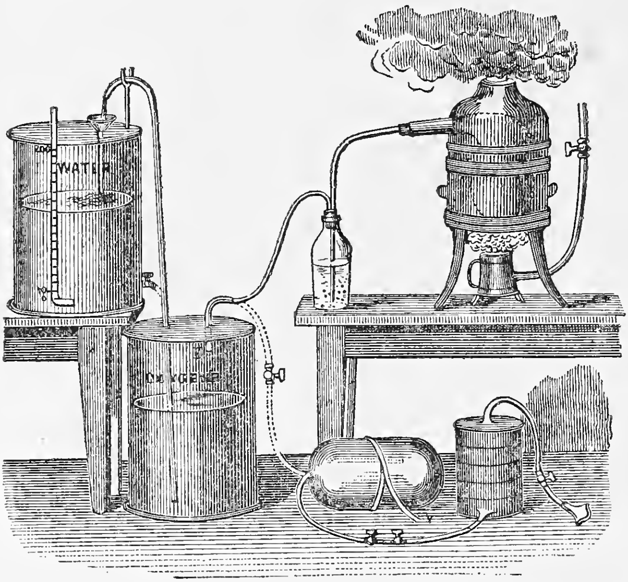


FIG. 2.—OXYGEN GENERATOR. ANOTHER FORM, WITH RECEIVERS AND DISPENSING APPLIANCES.

chlorate of potassium, which is formed in the beginning of the operation, takes place, since the violence of the evolution at this point might force out the tubes and corks of the apparatus.

"When the operation is completed, and we have obtained about two hundred and thirty or two hundred and forty litres of gas from each kilogram of chlorate, we tie the rubber tube which connects the receiver to the washing-jar to prevent the escape of oxygen, or, better still, we insert a stop-cock.

"If, now, we wish to fill the rubber receiver (gas-holder) of the apparatus, we adjust its open stop-cock to the outlet-tube,

and, removing the latter, we raise the water to the second reservoir; we replace it by another rubber connection, to which we fit a stop-cock, which serves to connect the second reservoir with its lower part.

"The stop-cock being opened, the liquid flows into the gasometer by the connecting tube, and displaces an equal quantity, or nearly its own volume, of oxygen, which is thus transferred to the rubber bag."

We can theoretically ascertain the quantity of gas introduced into the bag by weighing it, since oxygen is heavier than air. Practically, the weight of one litre of air being 1.30 grams,

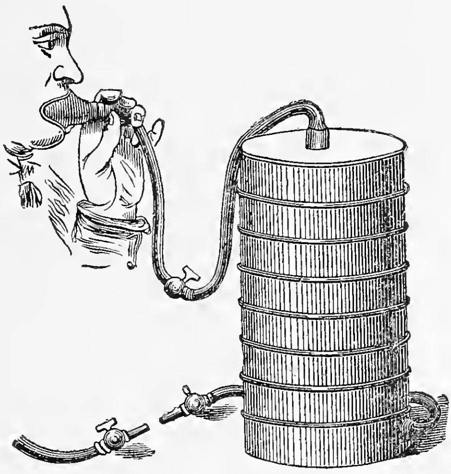


FIG. 3.—DISPENSING BALLOON, WITH INHALING MASK, ETC.

that of oxygen is 1.43; but this difference, which, as we see, is very slight, necessitates the use of a very sensitive balance, and the result, even in this case, may not be exact, on account of the variation caused by the atmospheric pressure, the temperature, and the degree of humidity, which varies at each moment.

To determine how much gas we introduce into the balloon [or bag], and to measure it, it is sufficient to follow, on the graduated scale of the reservoir, the subsidence of the water; and, since one litre displaces one litre of gas, it must descend twenty degrees or divisions, in order to transfer twenty litres of oxygen into the bag. We might, for that matter, gauge the capacity of the bag, and mark on it certain spaces corresponding

to twenty, thirty, or forty litres, and write on the bag thus gauged the number of centimetres required to contain a given quantity.

This gauging of bags has the further advantage of enabling us to introduce into them whatever quantity of air is needed to properly dilute the gas. For example, if we wish to have a mixture of two-thirds oxygen and one-third air in the bag, this is the way to proceed: Let it be, for example, thirty litres of mixture. We attach the bag—of which, for thirty litres' capacity, we will suppose the circumference, tested by a tape-measure, is seventy-five centimetres—to the apparatus, and introduce twenty litres of oxygen, noting the fall of twenty litres of water on the graduated scale. Removing the bag, we connect the stop-cock with a strong common bellows by means of a rubber tube, and inflate until the tape-measure indicates the desired circumference of seventy-five centimetres. As we have, for that matter, perhaps, already stated, the mechanism of the apparatus of M. Lemousin, for evolving and administering oxygen, has the advantage of enabling us to use the same water, so to speak, indefinitely, since the water displaced by the gas at the time of its evolution flows back into the same reservoir, when we wish to convey oxygen into bags and administer it.

II. ADMINISTRATION OF OXYGEN.

The balloon or bag, of which we have just spoken, serves not only as a gas-receiver, but also renders the latter readily portable. It does not constitute an inhaling apparatus, properly speaking; it is only a temporary receiver. This instrument, which M. Galante has very ingeniously constructed according to our suggestions, is likewise a reservoir of rubber, having, apparently, when inflated, the form of a little cask. The upper and lower parts are solid and unyielding disks, which approach and fit, one against the other, when it is empty. From the upper end projects a tube and mouth-piece for inhaling, and a stop-cock. Near the lower extremity is found an inlet-tube, furnished with a stop-cock, which is accurately adjusted to that of a balloon or bag filled with gas. The two stop-cocks being connected and open, if the inhaler is empty and folded upon itself, a light pressure exerted upon the balloon serves to force out the gas and cause it to enter the inhaler, care having been taken to close the outer stop-cock. It may be gauged in the

same manner as the bags in M. Lemousin's apparatus, and the circumference made to indicate upon a tape-measure the quantity of gas which we desire to introduce. [This apparatus is decidedly crude in the light of recent progress in this direction. See "Notes and Comments."—Trans.]

Its usual capacity is fifteen to twenty litres, while the balloons or bags may hold as much as forty litres of gas.

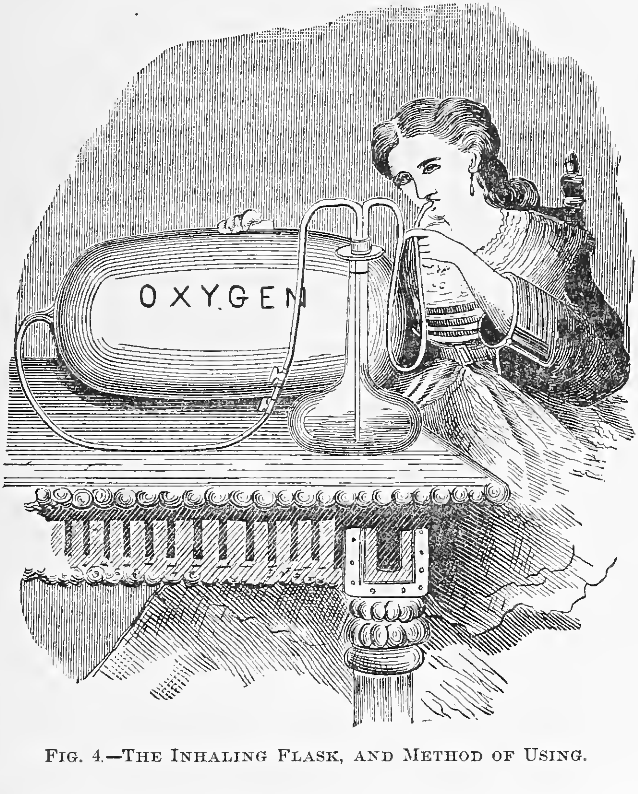


Fig. 4.—The Inhaling Flask, and Method of Using.

The following is the method of inhaling: The inhaler having been detached from the balloon or reservoir, the patient adjusts to his mouth the mask or mouth-piece, and, the stop-cock being open, he takes a few deep inspirations. At each inspiratory effort we watch the inhaler subside, and we can thus estimate the quantity of oxygen inhaled. To prevent the products of respiration from re-entering the apparatus, we direct the patient to close the lips and respire through the nose; but it is a

more certain method to compress the rubber tube between the thumb and index finger, at the moment of expiration.

In the process of M. Lemousin, the contact of oxygen with a larger body of water, as it passes, has the advantage of completely saturating the gas with humidity, a condition favorable and sometimes indispensable to its administration, since it has been often observed that it is irritating to the bronchial mucous membrane when it is inhaled directly from the washing-flask. [This was undoubtedly true of oxygen evolved by the author's hurried and fairly fulminant process, then washed through a single wash-bottle containing "milk-of-lime." Such gas unquestionably contained traces of chlorine and hypochlorous acid, as well as impalpable crystals of sublimed chlorate of potassium. It is now a thoroughly established clinical fact that perfectly pure oxygen is not in the least irritating, even when artificially desiccated.—TRANS.]

The respiration of oxygen directly from a rubber container has a great advantage—that of drawing directly from the reservoir, and of causing it to penetrate into pulmonary cavities, in large volume, at each inspiratory movement; but, although oxygen may be without appreciable chemical action on the substance of India rubber,* this latter has, nevertheless, an odor *sui generis*, which, under the alternate influence of humidity, arising from the products of respiration, and of slight elevations of temperature, may frequently prove very disagreeable to the patient. Talc-dust, which it is necessary to use to cover the surface of the sheets in manufacturing rubber, is also carried along by the gas when it is breathed, and produces at times a very disagreeable irritation of the bronchial mucous membrane.

We can easily obviate this inconvenience, when it occurs, by using an inhaling flask, which, after the manner of a *narghile*, removes the disagreeable odor of rubber, and intercepts the talc-dust, which is then deposited at the bottom of the water.

This modification, suggested by M. Lemousin, now added to the original apparatus, affords the additional advantage of enabling us to join to the action of oxygen the special action of certain substances which we dissolve, or which are suspended in

* M. Lemousin kept oxygen in a rubber balloon for six months, without its having been chemically changed, and without its having been, in any marked degree, penetrated by atmospheric endosmosis. [This is something of an exaggeration, according to my experience.—TRANS.]

the water which serves in the washing, such as tar, chloroform, iodine, phenic acid, etc. For any further description see the design of the apparatus as executed by M. Lemousin. (Fig. 2.)

The average dose which can be borne necessarily varies, according to the age, vigor, and condition of the patient, but, in general, we give from twenty to thirty litres [four and a half to six and a half gallons] per day, one-half in the morning, one-half in the evening.

It must not be overlooked, however, that, in causing a

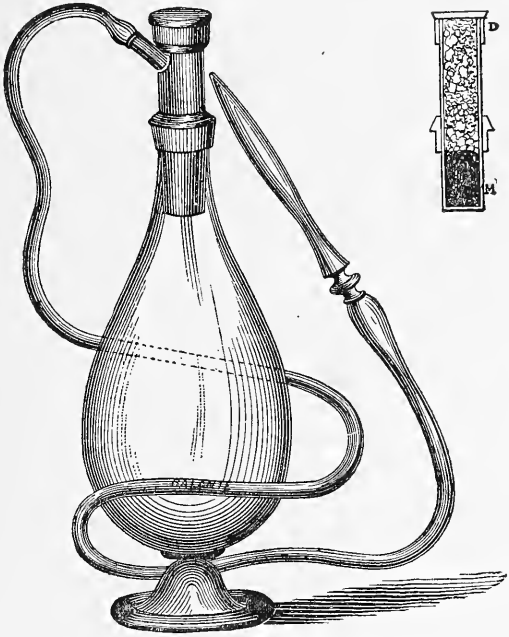


FIG. 5.—THE "NARGHILE" INHALER, WITH SECTIONAL VIEW OF NECK.
D, filtering material; M, aromatic or antiseptic substances.

patient to respire, under the above conditions, from an apparatus filled with pure oxygen, a certain quantity of atmospheric air is introduced by partial respiration through the nose.

III. OXYGEN FOR STOMACHAL ADMINISTRATION, UNDER THE FORM OF OXYGENATED WATER.

Last year we conceived the idea of administering oxygenated water. But water, as is well known, under ordinary atmospheric pressure, dissolves or absorbs but about one-twentieth of its own

volume. [Some experimenters say *one per cent.;* others, one-half this amount, or even less. This apparent discord arises from want of accuracy in making the experiments. If a uniform quality of distilled water, deprived of air and other gases, at a uniform or standard temperature, be used, this discrepancy will be greatly modified, if it does not entirely disappear.—TRANS.] Nevertheless, under a pressure of fifteen to eighteen atmospheres it will dissolve [hold in suspension] three or four times its own volume. Our idea was that in certain atonic diseases of the stomach and bowels the imbibition of this agent would prove an agreeable and appropriate stimulant. We therefore advised it in some cases of dyspepsia, in nervous women who were inclined to hysteria,—a class of patients in whom flatulent indigestion is quite common.

Again, in convalescence from certain diseases many patients do not do well. Deeming it appropriate to such cases, we arranged to follow this investigation, thanks to the co-operation of our former pupil, M. Lemousin, who prepared a supply of oxygenated water in bottles. By searching the British Library we found a very able work by Odier, of Geneva (1703), on this subject. On reading this work we were surprised to find that the Genevese physician had been actuated by the same motives as ourselves. We can scarcely do better than to repeat his conclusions, based on personal experiments:—

"Oxygenated water," says Odier, "revives the appetite and restores the energies. It increases the flow of urine, quiets spasms of the stomach, especially when the latter are accompanied by hysterical symptoms, and prevents recurrence of the attacks, especially if they are periodic.

"I have seen the mother of a family, forty years of age, for a number of years subject to nervous attacks and suffering intensely, as the result of a sudden and violent emotion. The attack commenced with spasms of the stomach, accompanied by choking sensations in the throat, which increased until suffocation was imminent. She could not lie down, and breathed only with the utmost difficulty. This condition, which was absolutely free from fever, lasted about an hour, after which the symptoms abated, leaving the patient with only a painful sensation of discomfort, which lasted several hours. On the following day she was perfectly well, but the next day, at exactly forty-six hours subsequent to the onset of the preceding attack, another

occurred, in the same manner, with the same symptoms and with equal violence.

"She was suffering the third attack when I was called in. I gave her, at first, quinine in large doses, during the next four hours, but without result. I then gave her powdered petals of field cresses (*Cardamine prætensis, Linn.*), a remedy recommended for the first time by Sir George Baker, and one which has given excellent results in nervous diseases. It failed in this case, although given in the dose of one ounce per day.

"Finally, I employed oxygenated water, in doses of a glassful every two hours, and, from the first bottle used, the remedy succeeded. The attack did not return, and the patient has remained in good health ever since.

"In another similar case, the mother of a family, of the same age, and having a similar constitution, was recently attacked by a bilious fever, during the course of which a nervous attack supervened, which manifested itself by spasms of the stomach, constriction in the throat, total loss of voice, a feeling of suffocation, and great distress, with involuntary discharges.

"I prescribed oxygenated water, but dysuria, which sometimes occurs in these cases, followed, and the use of the water was suspended. Some days later, the dysuria having ceased, the spasmodic attacks recurring periodically, with exact regularity, every eighteen hours, and refusing to yield to the most powerful antispasmodics, I reverted to the use of oxygenated water, and this remedy soon interrupted the paroxysms and prevented their return. The dysuria again occurred, but not until after the recovery of the patient from the more serious malady; and, as she took the water with discrimination, we were enabled to discontinue its use without inconvenience.

"I have seen several analogous cases, in which oxygenated water did great good. It has seemed to me that it ought to be classed with the list of antispasmodic tonics. I have seen it succeed very promptly in a relapse of melancholia, which had been previously relieved by black oxide of manganese,—a remedy which had subsequently failed. I also knew of a case of hydropsy, in which the water proved an astonishing success as a diuretic (1798).

"Since the foregoing was written (June, 1798) I have continued to make extensive use of oxygenated water, with uniform success. I have constantly observed the following results:—

"1. In a case of hysterical cramps and convulsions, particularly in the stomach and bowels, and especially when there was reason to believe that the spasms were of atonic rather than congestive or irritative origin; by means of the water I cured a Spanish girl, of twenty-five or thirty years, who had been for a long time subject to spasms, caused in the first place by over-intense spiritual excitement, and afterward much aggravated by the fatigue and constant vomiting she had undergone during a sea-voyage. All the known antispasmodics had been tried without success. Oxygenated water finally cured her, very promptly.

"2. In diseases of the chest, which are of an asthmatic rather than of a consumptive nature; I have seen a woman, of fifty-five years, for many years subject to severe dyspnœa, with also violent paroxysms of coughing and suffocation, resort to this water for several years, one after another, and realize greater relief than any other remedy could give her.

"I have also seen a man of about fifty, in feeble health, who, after an inflammatory catarrhal fever, suffered for a long time with weakness of the chest, so that the least effort of the voice caused great fatigue; which was in his case a much greater inconvenience than usual, since it was his occupation to give lessons, and he could neither speak nor read aloud without experiencing extreme fatigue. Besides, he had a constant feeling of oppression, of coldness and weakness in the legs and hips. After having unsuccessfully tried several other remedies, I at last tried oxygenated water, which succeeded very well and brought him decided relief.

"3. This water has appeared to act in a very satisfactory manner, in cases of feebleness and tedious convalescence following febrile diseases, when the subjects, without having any definite local disease, have not recovered their strength, appetite, and usual spirits.

"I used the water myself for some time following a tertian fever which had rendered me extremely weak, and I experienced very good results.

"4. Finally, it has proved of great service as a diuretic in cases of anasarca and hydropsy, accompanied with dyspnœa and lividity. One of my *confrères* saw a patient of this class, who had taken several other remedies without success, and who was cured by the use of oxygenated water, as if by enchantment, through its effect in procuring an abundant flow of urine. This

cure, which now dates back many months, seems to have been permanent.

"When I began the use of this remedy I observed some cases in which it appeared to cause marked symptoms of dysuria. I have since rarely observed this result; but, on the contrary, I have sometimes successfully used hydro-oxygenated water to check or assuage these symptoms."*

[The use of oxygenated water, both as a remedial agent and as a beverage, is being revived in this country. The best product is obtained by using pure, distilled water, rather than natural spring waters, for the reason that the latter, as is well known, are already highly aërated, either with carbonic acid gas or common air, and will not, therefore, accommodate as much oxygen as water from which all the air has been expelled by heat. It should be bottled under a pressure of one hundred and fifty to two hundred pounds. Birch, of England, found the chief objection to this water to be its flat taste. The addition of nitrous oxide gas is found to give piquancy to the taste and greatly adds to the exhilarating effects of the water. This combination has been the subject of an American patent, and a company in or near Boston is placing the water on the market.

The conditions in which it has been most thoroughly tried are those of the various forms of chronic indigestion, anorexia, incessant vomiting, inveterate headaches of both the nervous and congestive types, urinary and renal complications, including diabetes and Bright's disease.

Some of the results thus far reported are almost incredible. The water has been promptly and freely retained when the stomach has persistently rejected every other form of food and drink. It relieves certain forms of gastric distress almost immediately, acts as a pleasant diuretic if freely imbibed, never has caused dysuria, and can be taken with impunity by the most sensitive or debilitated invalid. In some cases a glass or two imbibed at bed-time has relieved habitual constipation, acting as a mild and pleasant laxative. In all the cases yet reported a combination of the two gases named has been far more effective, and is decidedly more palatable than either used separately.—TRANS.]

* Odier, Biblioth. Brit., April, 1799.

CHAPTER IV.

THERAPEUTIC ACTION OF OXYGEN.

I. *General Considerations.*—When we realize the important rôle that oxygen plays in the organism of animals and plants, we are genuinely surprised to see that physicians and surgeons have never more seriously sought to derive from it a use in therapeutics, and that the often happy efforts of Beddoes and his school have been abandoned to forgetfulness. Moreover, we all know that a man may live many days deprived of every species of food and drink, and that he may prolong his life for a long time if he is supplied with water sufficient to quench his thirst; whereas he can live but a few moments if air, or, what is better, oxygen, is refused him. He sees, then, only the necessity of keeping up, incessantly, in his economy a liberal supply of oxygen. In a normal condition, when in repose, a man makes from eighteen to twenty respirations per minute, and in each of these inspirations a considerable quantity of oxygen permeates the pulmonary parenchyma and vivifies the blood. According to Liebig, an adult absorbs, daily, about thirty-two and a half ounces of oxygen; hence, according to Lavoisier and Menzies, during the year, seven hundred to eight hundred pounds* of this gas has passed into the circulating medium, and has borne life with it. But this volume of oxygen, absorbed through the pulmonary tract, varies according to climate, and according to the temperature of the atmosphere. The quantity inspired increases when the temperature of the external air is lowered; consequently, there should be a proportionate increase in the quantity of carbon and hydrogen introduced with the food, in order that the oxygen may combine with these principles. It is evident that the new heat which replaces lost heat is supplied by the reciprocal action, one upon the other, of the oxygen inspired and the alimentary principles. It is therefore with plausibility that MM. Dumas and Liebig have likened the animal organism to a furnace, to which we must continually supply fresh fuel. "It is by introducing into the economy a proper quantity of material, which is there oxidized,—that is to say, burned by oxygen,—that we maintain a continuous evolution of heat. In

* From 62,000 to 71,000 gallons.—Trans.

winter, when we take more or less exercise in a cold atmosphere, and, in consequence, inhale a larger volume of oxygen, the demand we feel for food containing carbon and hydrogen is increased, on account of the increased quantity of oxygen absorbed. It is by satisfying this need that we maintain ourselves in condition to effectually resist the most intense cold. Cold lays hold of and rapidly overcomes a man who has abstained from food for a long period. Every one knows that the carnivora of the polar regions greatly exceed in voracity those of the torrid zone. In cold and temperate climates the air which incessantly tends to consume our bodies compels us to wage war against this destructive influence, that is to say, to struggle to acquire the means to resist its action; whereas in hot climates the necessity for labor is much less urgent, because the quantity of nourishment required is considerably lessened."*

It is this combustion which explains to us why the weight of the body does not increase, notwithstanding the large quantity of oxygen and of various foods which are taken into the system. Oxygen imbibed during inspiration reappears during expiration in the form of carbonic acid and water, if the combustion of hydrocarbons brings about their elimination by the lungs. As to plastic or nitrogenous matters, they are converted into uric acid, hippuric acid, and urea, and the sulphur of the latter is transformed into sulphuric acid. The secretory organs, and especially the kidneys, are charged with the elimination of these products. It is therefore due to oxygen that we appropriate these aliments which we are constantly introducing into our systems; but, this agent wanting, all our functions are disturbed, animal heat undergoes a decided decrease, and the secretions themselves are profoundly altered. The circulation languishes, since the blood no longer imparts the needed stimulation to the blood-vessels. Assimilation and elimination of nutritive materials, which complete the vital *circulus*, are arrested. The spinal cord and brain no longer vivified by blood sufficiently oxygenated, intelligence, sensation, and motion are all greatly modified, as we have repeatedly demonstrated. If any portion of the human body ceases to receive blood sufficiently arterialized, that is to say, oxygenated, sickness and death soon follow.

Oxygen is therefore the principal agent of our existence. If, then, supposing that we could decidedly change the compo-

* Liebig, Lettres sur la Chimie, p. 236.

sition of the atmosphere in which we live, our organizations remaining the same, death would be the result of this modification. We realize, therefore, that the hygiene of man, in health and disease, must have for its object not merely the assurance of sufficient nourishment, a comfortable habitation, and clothing appropriate for the climate, but, above all, must provide him that volume of respirable air which is indispensable to the regular accomplishment of the respiratory function. It is, of course, important that man should have nourishment and a habitation suited to his needs; but if air, or, virtually oxygen, is wanting, we shall see him languishing, enfeebled, and incapacitated for physical exertion, bodily activity, and intellectual labor. What is it we accomplish when we send our convalescent invalids or our debilitated operatives to breathe the air of the country, or sea-air? We subject them, in the first case, to a more life-giving atmosphere, and, in the second, we cause them to breathe under an increased atmospheric pressure, which increases the quantity of oxygen absorbed. If we add to these new conditions walking and muscular exercises, we shall largely increase the flow of arterial blood in the muscles, and distribute a greater quantity of oxygen. Thence, naturally, an acceleration of vital processes, a modification in the decomposition of substances which are unfit for use in the organism, and which should be eliminated under the forms to which we have already referred. Then will follow, also, as an immediate consequence, a greater need of respiration, and from this an increased appetite and a more active digestion. Oxygen becomes, in this case, the reviver *par excellence.* It induces a more uniform movement of all the functions and restores the strength of the enfeebled organism. Here we see an explanation of the renovations which are accomplished in the country, or on the sea-shore, with individuals debilitated by overwork or by disease. What can be accomplished in the country or on the sea-shore we have often accomplished by inhalations of oxygen. This is so true that if we give oxygen in extreme doses, as we once did, without any inconvenience to the respiratory organs, we shall see that, notwithstanding the appetite is considerably increased, the subject loses flesh; and if, in our observations, it had been possible for us to determine the quantity of carbonic acid exhaled, it is probable that the enormous figure of five hundred and forty litres, which a man exhales in twenty-four hours, would have been much exceeded. Thus,

the action of oxygen, as we understand physiology, operates primarily upon the blood and secondarily upon the nutrition. Each blood-globule seizes it and carries it into the organism, from which it returns charged with carbonic acid. The blood-globule is, then, the true agent of hæmatosis; and thus, as we have shown in treating of the physiological character of oxygen, the latter must also have an important agency in sanguification. Moreover, in reviewing our experiments with pigeons, rabbits, and dogs, we see that this opinion is well founded. Without doubt, other organs, as the spleen and the vascular glands, co-operate to this end, and *it is very probable that the formation of blood-globules, which takes place in these organs, awaits its complete development from contact with oxygen;* since this appeared to result in one of our experiments, in which we saw the spleen assume a scarlet tint from the effects of an injection of oxygen into the portal vein. *Oxygen is therefore the great modifier of the blood, the soil from which all the organs are developed and sustained; while it is also the source of animal heat and of the secretions.* The vessels in which it circulates are the channels by which the products of the metamorphosis of the tissues are carried into the secretory organs and finally expelled from the body.

However, oxygen is not the only formative agent of the blood-globule. It requires the aid of plastic or albuminous materials, and finally of iron, which is one of the chief ingredients of the coloring matter of the blood. Whenever the number of these globules is diminished, from one cause or another, hæmatosis is modified, and with it all the other functions. What shall we do to remedy this condition? We may prescribe iron and restorative nutrition; but *these will not accomplish the end we wish to attain, except on condition that they are combined with oxygen.* Every one knows that anæmia and chloro-anæmia are found to be immeasurably better treated if we add to the indicated medication exercise in the open air of elevated regions or at the sea-shore.

The action of oxygen is both chemic and dynamic, and when Fourcroy and his school sought in its, so to speak, topical action on the pulmonary tissues a therapeutic agent, they committed an error which the labors of Lavoisier ought to have made impossible. Perhaps Beddoes better understood the chemic and dynamic action of oxygen; but, we say it very em-

phatically, it is an established fact which they ignored, and upon which the labors of Magnus and Claude Bernard have thrown a strong light: *this is by far the most important of the gases of the blood.* Let us hope that at some future time these gases will be subjected to the same investigation, in health as well as in disease, as those on fibrin, albumen, and blood-globules, to which MM. Andral and Gavarret have devoted themselves. Will not these investigations be the complement of studies which have established modern hæmatology,—a study of quite recent origin, and one which has thrown new light upon the subject of internal pathology?

Several objections have been made to the use of oxygen inhalations. Why, says one, give oxygen artificially prepared, when we find it, especially in the country, under normal conditions, and in a mixture appropriate to the needs of our physical organization? Undoubtedly it would be desirable if we could subject all our invalids and convalescents to this happy influence. But this is not possible; and, admitting it, we do not yet know but that, if the most thorough artificial oxygenation of the blood gives such therapeutic results, who can say that an artificially increased arterialization would not even put us in condition to more easily resist certain epidemic influences? An objection apparently more serious is this: breathing air too highly oxygenated may be positively harmful to the organism. That is true. It is found that at the outset of the experiments made with this gas serious accidents occurred. Those invalids who were shut up in the cabinets, in which they breathed for a considerable time an atmosphere more or less charged with oxygen, evidently overshot the end which it was designed to attain. Hence the failure of Fourcroy and the abandonment of therapeutic oxygen. But, some one will say, what can the breathing of ten, fifteen, twenty, thirty, or forty litres of oxygen do for the human organism when we think of the volume of blood to be vivified and the short duration of these inhalations of oxygen? In the first place we would refer to the preceding chapter, in which we saw the animals, used in experiments, presenting, at the end of a longer or shorter period, an apparent increase of the volume of the blood, as if, under the influence of this gas, certain organic elements were transformed into blood. The circulation is, as every one knows, extremely active. We have shewn, in the chapter devoted to emphysema, that at the end of twenty-four

seconds sulphuretted hydrogen introduced into the rectum or the cellular tissue of a rabbit was eliminated by the bronchial tubes. It follows then, from these experiments, as well as from others to which we might refer, that in the space of twenty-four seconds each molecule reaches and traverses the lungs, and is brought in contact with oxygen. What is the result when we cause pure oxygen or highly oxygenated air to be inhaled for four or five minutes? We subject the entire volume of the blood for a certain number of times to a contact with the vivifying gas. Each blood-globule exhales carbonic acid, with which it is impregnated, and is completely charged with the full quantity of oxygen which it is capable of absorbing. There results, necessarily, a greater exhalation of carbonic acid, as has been verified by M. Grassi, and a transmission to the entire organism of a much greater quantity of oxygen; whence a more lively excitation of all the functions, and a more rapid, and doubtless more complete, combination with hydrocarbonic elements and azotized materials. Let an individual, burdened with fat, submit himself to a proper diet; let him indulge freely in active exercise on foot in the country; he will soon discover that his superabundance of fat is disappearing. What occurs in this case? By walking he accelerates the circulation and the respiration; more oxygen enters his blood, and the mass of fat which overloaded his system is oxidized and disappears. What we assert of the obese individual we say also of the man with urinary calculi. The latter, lacking for exercise, does not completely oxidize the azotized products which he ought to eliminate. Increase in this man muscular waste, and reduce his diet, and often you will see the gravel disappear. In this case oxygen causes a more complete combustion of albuminoid substances, and eliminates them under the form of urea, etc. In large cities men frequently cultivate sedentary habits, and excesses of every kind frequently aid in deranging the health; a dietary too liberal, and not at all comporting with the daily exercise, overburdens the body with carbonaceous or nitrogenous principles, which an insufficient respiratory action is unable to eliminate. At other times the reverse of this phenomena takes place. There is a lack of exercise, or an excessive exercise, added to an unhealthy dwelling and insufficient nourishment, which step in to profoundly change the organism. Well, in these cases, the regimen and the most appropriate treatment

prove to be insufficient to restore the strength of the system; but let oxygen, this modifier of the nutrition and of the capillary circulation, be administered, and we shall see the disorders above mentioned removed.

We have known a diabetic patient, with whom exercise at the sea-shore, under an atmospheric pressure greater than that of Paris, produced a decided decrease in the quantity of sugar daily excreted. Sojourn at the sea-shore had the same effect on him as his stay at Vichy. M. Mialhe cites the history of a diabetic who learned to appreciate to a nicety the exact number of kilometres that he must do to offset the effects of a little gormandizing on saccharine or starchy elements. M. Bouchardat long since proved that the best adjuvant of diet in the treatment of diabetes is the regular use of gymnastics. In corroboration of these facts we can quote results which we have obtained with inhalations of oxygen in case of several diabetics, *without any change in their diet.* We have seen the quantity of sugar in their urine decrease in a remarkable manner. The sum total diminished in these cases, and in a few days to the extent of one-half of that which had been established as normal. M. Berénger-Feraud, a young and very distinguished marine surgeon, as also Dr. Y-van, both of whom have, at our suggestion, used inhalations in the treatment of diabetes, have also very favorably modified the condition of their patients. Undoubtedly we have proceeded only upon the symptoms of the disease; but in the existing state of science, what other treatment can we administer to the diabetic; since science is not decided either as to the nature or as to the real cause of the disease?

An important physiological circumstance which materially aids in retaining oxygen in the blood is the presence of a large proportion of alkaline elements in this liquid. This fact, pointed out by M. Chevreul, has become, in the hands of M. Mialhe, the basis of a rational treatment of diabetes. Under the influence of alkalies—Vichy water, for example—the blood appropriates a greater quantity of oxygen and burns up the excess of saccharine matter. Nothing is easier than to establish a therapeutic system on this basis, to wit, the administration of alkalines and inhalations of oxygen, in the treatment of diabetes; all the better because, whatever may be the theory we adopt as to this disease, the therapeutic object is always the same—to destroy the

glycosuric matters formed.* But we do not wish to insist further upon this point. We refer the reader to the scholarly work of our friend, Dr. Marchal (de Calvi). In his very remarkable "Letters on Chemistry" he dwells much on this subject, and we cannot do better than to reproduce his opinion on this point:—

"Myriads of organic compounds which, by themselves, at the ordinary temperature, or at that of the animal organism, are wholly lacking in the quality of combining with oxygen, that is to say, of burning, acquire this quality when brought in contact with a free alkali. (Chevreul.) This influence of the alkalies is particularly striking in case of certain coloring matters, which, under these circumstances, become decolorized; or with certain colorless substances, which thus take on color and are then destroyed. Carmine, one of the most permanent coloring materials, the coloring matter of Campeachy wood and of Brazil wood, the coloring matter of the blood, when dissolved in caustic potash, keep without change for months; but as soon as this solution is brought into contact with air or oxygen the gas is rapidly absorbed and these coloring matters are destroyed. (Chevreul.)

"The colorless solution of gallic and pyrogallic acids is changed to deep red in the presence of potash and in contact with air, and is destroyed in the space of a few minutes. Alcohol itself is oxidized and darkened at ordinary temperatures, when it contains free alkali.

"Sugar of milk and grape-sugar, in the presence of alkalies, liberate the oxygen of even the metallic oxides, at ordinary temperatures.

"A similar effect is produced by the alkalies in the blood; they both favoring and increasing the combustibility of the respiratory foods.

"This influence of the alkalies is very marked in case of the salts formed by organic acids introduced into the circulation. We have for a long time observed that the urine becomes alkaline when savory fruits, as cherries, strawberries, apples, etc., are eaten. All these fruits, as well as the juice of grapes, tubers, and herbs, contain alkalies, in the form of acid vegetable salts,

* If we are to realize anything beyond mere temporary alleviation from the use of oxygen in this insidiously fatal malady, it must be by so invigorating and correcting the assimilative function that the glycosuric formations (or degenerations?) will be prevented at their source. There is reason to hope that an intelligent and thorough use of the remedy will do this.—Trans.

usually as malates (stone-fruits, pineapples), citrates (kernel-fruits, gooseberries, potatoes), or as tartrates (grapes). Now, it follows, from the investigations of MM. Gilbert Blanc and Wœhler that the foregoing salts, taken separately, comport themselves like the salts contained in the different vegetable substances introduced by the mouth or in the form of baths; the citrate, tartrate, malate, and acetate of potash reappear in the urine as carbonates.

"The acids of these salts being introduced into the blood in a state of combination, either neutral or acid, are burned as completely as if in the most perfect combustion apparatus. The alkaline carbonates contained in the urine of the herbivora have their origin from the same source. They are derived from organic salts, having an alkaline base, contained in the food.

"It is, moreover, by contact with an alkali that uric acid is burned in the system. The urine of rabbits to which we administered large doses of uric acid in the form of urate of potash (two to two and a half grams) did not contain uric acid. This acid was converted into oxalic acid and urea, of which the quantity was at least five times the quantity of urea in normal urine. (Frerichs.) Now urea, as we know, represents carbonic acid in which one equivalent of oxygen is replaced by its equivalent of amidogen. The cause of the extreme combustibility of these substances in the system is evidently due to the alkalinity of the blood, as the simplest facts prove. The herbivora consume, in their food, a large proportion of free acids, which are disseminated throughout the circulation and disappear as acids combined with alkalies. There is unquestionably produced in their organism, as in that of carnivora, uric acid, arising from imperfect combustion of plastic material; but, in a state of health, this uric acid never appears in the urine of animals rich in free alkali. This phenomenon is satisfactorily explained by the presence of alkaline carbonates in the blood. Vegetable acids introduced into the blood, or uric acid resulting from the metamorphosis of tissues, decomposing the alkaline carbonates and forming neutral salts which are quickly decomposed by oxygen circulating in the system, and carbonic acid, made free, is eliminated by the lungs."*

It follows from this lengthy quotation that alkaline medication, so long employed in the treatment of gravel, has for its

* Nouvelles, Lettres sur la Chimie, p. 171 et suiv.

results the retention of an increased quantity of oxygen in the blood, of a more active and thorough combustion there of plastic elements or albuminoids, and the conversion of uric acid into urea, the form under which azotized matters, completely oxidized, are eliminated from the system. Certainly we will not pretend to limit the effect of the alkaline salts to this simple rôle; the very method following which we prescribe Vichy water, at Pougues and at Carlsbad, is too complicated to have a limited or single effect; but that which proves the powerful action of these waters as retainers of the element, oxygen, is this, that it is often easy, on the appearance of gravel, to check the production of uric acid by modifying the diet and compelling the sufferers to take exercise. An indirect proof, which further corroborates this view, is that gravel very rarely occurs in men who pursue a manual occupation in the open air. In this case it may be said that their food is not too highly animalized in nature. This is true; but, even admitting it, this observation does not invalidate the fact which we have above cited. We can then, we believe, with advantage, place individuals afflicted with gravel upon inhalations of oxygen, at the same time that we modify the diet and administer an alkaline mineral water. These are admittedly but theoretical views, but in this matter has not empiricism outdone, in this respect, the recognized principles of modern chemistry, and is not our proposition very naturally deduced from the facts cited by Liebig?

We note with pleasure that M. Roubaud, the skilled inspector of the waters of Pougues, reaches the same conclusions in a very interesting brochure published this year on the springs of Pougues.

But do the alkalies alone possess the property of endowing the blood with the faculty of absorbing or dissolving a much greater quantity of oxygen? When we subject our patients to an alterative treatment,—iodide of potash, for example,—do we really know what takes place in their systems? Here is a field of study wholly unexplored. What occurs when we give cod-liver oil in large doses, an empirical, yet often beneficial remedy? Through what elements does it act on the organism? We do not know; but a fact which has not escaped the English Dr. Birch is that *cod-liver oil succeeds better in the country, or at the sea-shore, than in large cities.* In these instances it is evidently better absorbed, and under the influence of a stimulating atmosphere it undergoes more perfect combustion. Why do we not,

in certain scrofulous manifestations, combine with it inhalations of oxygen? [Dr. Humphrey, of Whitewater, has reported some very encouraging results from the use of oxygen in connection with cod-liver oil. He does not, however, rely on inhalation, but utilizes the gas by enemata, introducing, per rectum, two to four quarts, half an hour after injecting two ounces or more of emulsified oil. See further, on this point, in "Notes and Comments."—TRANS.]

But enough of generalizations. Let us come to the application of oxygen. We will study:—

II. *Its application to medicine.*

III. *Its application to surgery, which we will treat under two heads:*

(*a*) *Local applications.*

(*b*) *General applications or inhalation.*

IV. *Application of oxygen in the treatment of certain medical affections.*

Before dwelling on the practice in which we have administered oxygen in the treatment of a certain number of diseases, called medical, we will reproduce a table of cases in which Beddoes prescribed it. This table is far more interesting than is indicated in the mere matter of cases and failures. Moreover, the English author has taken pains to assert in his work that if oxygen has not always succeeded it has, at least, done no harm to any of his patients. For our part we can make the same observation, and in equally good faith. We have not cured all the patients whom we have caused to inhale this gas, but we are certain that we have not injured a single one of them.*

* Demarquay's frequent reiteration of an ingrained apprehension lest he might in some way injure his patients by excessive or inopportune doses of oxygen, is but a natural expression of the prevailing impression that oxygen may be a powerful, but is, *pro tanto*, a dangerous therapeutic agent.

The fact is, and yet a majority of those who have not given the subject any special study do not realize it, that *except by forcible or actually compulsory means the system will not absorb more oxygen than it can utilize.* Admitting this physiological truism, it will readily follow that an excessive administration of the agent (if by inhalation) results, ordinarily, in nothing more serious than a mere waste of the gas,—the excess being simply rejected by expiration.

Of course, this rule does not obtain when the gas is injected into the blood, and perhaps not entirely when it is forced into the bowel, injected into the cellular tissues, into the pleural or abdominal cavities, or into mucous or serous membranes. A little reflection on this point ought to disarm the most cautious practitioner of all timidity in the matter of prescribing it.

There are exceptions to this as to all general rules, but this is not the occasion for their detailed discussion.—TRANS.

EFFECTS OF OXYGEN ON DIFFERENT DISEASES.*

DISEASES.	Number of Cases Cured.	Number of Cases Relieved.	Number of Cases Not Relieved.	Total.
Malignant ulcers, ...	2	2	0	4
Leprosy, ...	5	0	0	5
Convulsions, ...	3	2	0	5
Cataract, ...	0	2	3	5
Chlorosis, ...	5	2	0	7
Epilepsy, ...	1	0	5	6
Asthma, ...	10	9	3	22
Cancer, ...	0	3	0	3
Hydrothorax, ...	2	1	1	4
Hypochondria, ...	0	1	0	1
Dyspepsia, ...	3	1	0	4
Hydrocephalus, ...	0	1	0	1
Cephalalgia, ...	2	2	0	4
Opium poisoning, ...	1	0	0	1
Paralysis, ...	2	1	1	4
Scrofulous tumors, ...	2	1	0	3
Deafness, ...	1	0	0	1
White swelling, ...	1	0	0	1
Scurvy, ...	1	0	0	1
Venereal disease, ...	1	0	0	1
Melancholia, ...	1	1	0	2
General debility, ...	1	0	0	1
Continued fever, ...	1	0	0	1
Intermittent fever, ...	1	0	0	1
Cold extremities, ...	1	0	0	1
Anasarca, ...	2	1	1	4
Totals, ...	49	30	14	93

It follows, from the foregoing table, in view of considerations which we will now submit, and especially from cases which will be cited in the succeeding pages, that oxygen can render very great service in the treatment of anæmia, and of dyspepsia associated with anæmia. We have not had opportunity, in the hospitals, to administer oxygen in these cases; this we realize, not having had charge of the medical service. Therefore, we have not many times administered oxygen in anæmia and dyspepsia, save as a general means of combating these two complications of other more or less grave pathological conditions.

But in our private practice we have several times administered it with great success. Our first patient was a lady convalescent from metro-peritonitis. She had become profoundly anæmic; a

*This table, based on the work of Beddoes, is borrowed from the British Library, vol. vi.

flatulent dyspepsia, complicated with vomiting, rendering alimentation impossible. Under the influence of oxygen all these symptoms subsided, and the invalid was restored. In the case of another woman, who was anæmic and dyspeptic in the highest degree, her strength greatly reduced, the most varied treatment, as in the preceding case, had been resorted to without any result. Under the influence of inhalations of oxygen her strength and appetite returned, and the anæmia was removed. This lady became *enceinte* at the end of six weeks or two months of treatment.

In order to present these cases a little more circumstantially, we will give a curious case in point, borrowed from Beddoes, and another from Dr. Thierry-Mieg, who has kindly reported it to us. Both demonstrate the influence of oxygen upon these two pathologic conditions.

Case I. *Extreme Debility—Treatment by Oxygen.**—"Bennett Street, St. James, July 4, 1796. Mrs. Roberts, of 43 Picadilly, has been an invalid for more than twelve years. She has been treated, successively, by the most capable practitioners,—Doctors Pinkston, Cadogan, Cheston of Gloucester, Farmer, and by a distinguished physician of Bath. Finally, she found herself so reduced that she was compelled to keep her room, and was scarcely able to stir from her bed. She was then placed under the care of Dr. Merryman. She had no appetite; prostration extreme; facies hippocratic; insomnia persistent. Having been called to see this invalid, I at first prescribed some aperients, then cinchona and lime-water. Finally, I placed Mrs. Roberts upon inhalations of oxygen. This vital air thoroughly revived the patient; the cachectic aspect rapidly disappeared; her color returned; the appetite and the cutaneous respiration were re-established, and the general improvement was so prompt and so rapid that in less than a month she enjoyed a condition of perfect health, which continued during more than four months' subsequent observation."

Case II. *Anæmia Following a Bad Parturition.*†—"Mrs. L., of Boston (U.S.A.), thirty-two years of age, was delivered of twins in March, 1862, followed by adherent placenta; removal, followed by very severe hæmorrhage. From this followed a condition of profound anæmia, from which this lady, who was

* *Op. cit*, part iv, p. 65.
† Reported by Dr. Thierry-Mieg.

of a lymphatic temperament, and exhausted by several consecutive confinements, was unable to recover, notwithstanding the use of ferruginous preparations and of divers sojourns in the country. She was advised to go to Europe.

"In July, 1864, she arrived at Spa, where the use of the ferruginous waters, at first, did much good; but, after the first three weeks, the amelioration was not maintained, the appetite was lost, and she decided to make a month's trip to Switzerland. Reaching Paris in September, 1864, she was still very anæmic, feeble, unable to go out except in a carriage, and absolutely without appetite.

"Having heard, through M. Demarquay, of the great utility of oxygen in these cases, I advised Mrs. L. to inhale, twice a day, at least an hour before each of the two principal meals, at first seven litres of oxygen at a time; the next day, eight, then nine, increasing to fifteen litres at a time, making thirty litres per day, and to continue this dose. Added to this, a little massage of the muscles; roasted meats, rare-done; Bordeaux wine, and every day a little exercise in the open sunshine.

"She commenced the inhalations of oxygen on the 24th of September. September 30th, very little change yet. During the first days of October Mrs. L. began to have an appetite. A few days later the appetite became very strong, and the digestion was well performed. The mental faculties were exalted. Mrs. L. by this time was capable of taking more exercise. She felt better than she had been for two years, and continued to respire thirty litres of oxygen *per diem* until the 8th of December; that is to say, the inhalations were continued for six weeks. She considered herself entirely cured, having recovered her strength, a fair degree of *embonpoint*, an excellent appetite, and lively spirits. Meanwhile, considering her temperament, I advised the use of cod-liver oil and hypophosphite of iron, with some pepsin-powders whenever her appetite failed.

"Mrs. L. passed an excellent winter, and she herself attributed to oxygen the marked amelioration in her condition which supervened; when, in March, 1865, like a shock, she was impressed with a sudden fear, which was succeeded by a contrariety of bad feelings and weariness. The appetite disappeared, her dyspepsia returned, and pepsin, together with iron and nux vomica, failed to control it. It was then that inhalations of oxygen were resumed, and a better state of feeling soon became

apparent, when, at the end of three weeks, the date of departure having arrived, Mrs. L. was obliged to quit Paris.

"At the date of this writing I learn that a sojourn in the Tyrol has had very good effect, but I regret not having again prescribed the oxygen inhalations at Paris, at least six weeks before the departure of Mrs. L., considering that the last three weeks gave much greater results than the first three.

"This report tends also to confirm a principle well known to physicians in its applicability to ferruginous and tonic medication in general; that is, we ought not to stop at a temporary success, but should return to the use of the same means after longer or shorter intervals. I have reason to believe that if, instead of omitting oxygen inhalations for four months in case of Mrs. L., I had caused her to resume them at the end of three months after the first period, the magnificent results obtained at first would have been maintained, in spite of the unexpected causes of debility which supervened. In support of this opinion, I would say that a very distinguished physician of Boston, who was the regular adviser of this patient, made her promise to persist in the use of tonics and iron for a year or more. And she recalls the fact that the waters of Spa lost their good effect at the end of three weeks. I would therefore have been justified in directing her to return to oxygen sooner, but the improvement had been so remarkable that it reassured us beyond measure; besides, the knowledge of a new remedy is acquired only gradually."

In reviewing the table previously given, we are impressed by the number of diseases to which oxygen has been applied; hence, we are not astonished at any want of success. Our own medical practice, however, is far from being as extensive as that of the English physician. In reporting our own cases, we will, at the same time, make known results obtained by Hill, which are not less interesting than those of Beddoes.

The disease for which oxygen has been most prescribed is asthma; in fact, we note that twenty-two cases have been subjected to this method of treatment, and that ten were cured, nine improved, and that but three were found to be wholly refractory. It is probable that the word *cure* implies that oxygen has interrupted the paroxysms, and not that it has caused the disease to permanently disappear. We presume that those who have read the "Clinique Médicale" of Professor Trousseau, and

the able article on *Asthma* by our friend G. Sée, in the "Nouveau Dictionaire de Médecine et de Chirurgie Pratique," will be of our opinion. Nevertheless, the fact is interesting, and deserves to be so much the more fully recognized, that we have also obtained, in case of individuals suffering with asthma, the most remarkable success; not that we have performed permanent cures, but we have been able, in many cases, to prevent the onset of the paroxysms.

The following cases are selected from the practice of Beddoes and from our own:—

Case III. *Nervous Asthma Treated by Oxygen.**—"It is with the greatest pleasure that I publish the following case, in the hope that other persons may find help from the same treatment. For nearly eleven years I was subject to frequent paroxysms of nervous asthma which caused me unspeakable suffering. Blistering the chest and expectorant medicines relieved me usually, but not without several hours of agony. Damp weather distressed me far more than freezing weather. My strength was very much depressed, even for a long time after the oppression had left me. About the middle of last September (1795) I began to inhale oxygen, under the advice and direction of Dr. Beddoes. After a few weeks a very evident improvement in my health took place. Toward the end of October I caught cold, and experienced a quite intense paroxysm of asthma, though less severe than formerly. Since that time up to the present I have had but five paroxysms, all much milder and of shorter duration. Each spring, for many years, I was quite indisposed, but this year I was not sick for a single hour, and during the last ten months I have enjoyed better health than during a number of preceding years. Heat and dampness affect me less than formerly, and, quite in contrast with my former experience, I can take cold without incurring an attack of asthma. I have respired oxygen about nine months, once per day, with some slight interruptions.

"At the beginning of this month I stopped the treatment, hoping to be able to pass the summer without this auxiliary, and with the intention of reserving it for times when I may require it.

"J. Hare, Esq.

"Conduit Street, July 29th, 1796."

* Beddoes, *op cit.*, part iv, p. 49.

Case IV. *Asthma—Curious Effects of Oxygen and Hydrogen Administered Alternately.**—"A gentleman, Mr. T. D., was referred to me by Mr. Baker. He had been suffering from asthma for nearly thirteen years. He had lost appetite, and experienced extreme muscular weakness; his pulse was languid and his extremities cold. I prescribed for him superoxygenated air. After six weeks of this treatment, aided by appropriate remedies, the asthma was not mitigated (which surprised me, since by this method I had that winter and the preceding ones relieved and cured several asthmatics). It seemed, on the contrary, a little increased. The patient at this time incurred a very severe cold. Fearing lest the recent oxidation had favored the inflammatory symptoms, I prescribed to him the respiring of hydrogen gas diluted with atmospheric air. The feverish heat and irritation of the chest immediately disappeared. He has repeated this inhalation, and is now persuaded, knowing as he does his own constitution and the persistency with which colds affect him, that hydrogen has prevented, or rather cured, the catarrhal attacks. Upon interrogating this patient more in detail, I learned that he had fallen into the habit of curing his paroxysms of asthma by going to the theatre, and, in fact, he found relief there, provided he took care to secure a place in the upper gallery, but not if he went into the parterre boxes. I learned also that the east wind blowing with violence invariably brought on a paroxysm, if he walked against the wind; and that he was never quite so well as when he found himself in a dense crowd, and in a damp and foggy atmosphere.

"When Mr. D. breathed a superoxygenated atmosphere, even though the oxygen was much diluted, he was awakened the next morning at a very early hour by a sense of oppression, which was followed by a long paroxysm of coughing, irritation of the lungs, and dryness of the tongue. When he inhaled hydrogen he went to sleep sooner than usual, he slept well, and had none of the foregoing symptoms. Since the catarrh had been removed by hydrogen I conceived the idea of giving him a little oxygen during the day, and some hydrogen at night. By the use of this treatment he quite recovered. He went to sleep almost immediately after inhaling hydrogen, and was almost entirely relieved of all his former symptoms."

This last case is very remarkable. In this instance it was

* Beddoes, *op. cit.*, part i, p. 78.

not oxygen, but hydrogen, that proved effective. We will dwell more at length on this point in the chapter devoted to this latter gas. We have also had opportunity to cause asthmatics to inhale oxygen, and in many cases we have obtained prompt relief. We ought to add that in the above case we had to deal with a purely nervous affection, without any serious complication of the lungs or heart.

Case V. *Asthma Treated by Oxygen.**—Mr. X., aged nineteen years, born in Scotland, was placed, on December 10, 1863, under the care of M. Demarquay for hydrocele. He recovered completely from this disease; but was seized with a paroxysm of asthma the next day after he arrived at the hospital. M. Demarquay thought to treat the asthmatic symptoms by inhalations of oxygen; and, strange to say, these symptoms yielded, as if by enchantment, as soon as the patient inhaled the vital air. Note, in addition, some details of the pathological history of this young Scotchman, and the results which were obtained as to the condition of his lungs under the influence of oxygen inhalations.

His mother early succumbed to tubercular disease of the lungs. His father is still living, and enjoys perfect health.

Since he was eight years of age he has had paroxysms of asthma. Until he was thirteen or fourteen the paroxysms occurred regularly once a month, and since each paroxysm lasted about a fortnight, the patient experienced but a moderate degree of health, even during the last half of the month. His general health was, therefore, quite variable. From his fourteenth to his eighteenth year the paroxysms, although less frequent, continued meanwhile to afflict him every two or three months. At eighteen he left Scotland for France; and, thanks to the more genial climate of our country, the asthma diminished in both its intensity and its frequency. Since his sojourn in France he has had but two paroxysms of asthma,—the first about three months ago, and the second since his admission to the hospital.

December 13th. Last evening, at the onset of the attack, he inhaled twenty to twenty-five litres of oxygen. From the first inspiration he was better, and after having appropriated all the oxygen from the bag the paroxysm ceased entirely.

December 17th. At nine in the evening he was again seized with asthma. At once he was made to respire oxygen,

* Reported by the hospital interne.

and the symptoms of dyspnœa disappeared as if by enchantment. According to the statement of the matron in charge, the bag, which contained twenty-five to thirty litres, was not yet emptied when the patient fell asleep.

From the 18th to the 22d the patient had no recurrence of asthma.

On the 22d, awakened by a paroxysm, he reverted to inhalations of oxygen, which were followed by immediate relief.

From the 23d to the 27th he was comfortable.

On the 27th the patient began to suffer from dyspnœa; a few inspirations of oxygen promptly averted the paroxysm.

Case VI. *Employment of Oxygen in an Asthmatic Paroxysm.*—Alfred D., twenty-seven years of age, employed by the government, entered the Municipal Hospital, January 23, 1865, suffering from an indurated chancre, complicated with an inflammation of the inguinal glands.

Before his entrance into the service Mr. D. had been exposed to severe cold weather, which brought on a mild bronchitis, an indisposition to which he says he is quite subject.

On the 24th he was seized with a paroxysm of asthma, which, without being specially painful, embarrassed him very much, and compelled him to keep a sitting or upright posture. These paroxysms of asthma, he says, have been constant and inseparable companions of colds, to which he has been subject. They last three or four days, and then disappear.

The 25th the oppression which he had experienced increased. He was somewhat relieved in the evening by a mustard foot-bath.

The 26th the oppression of breathing was still the same. Twenty litres of oxygen were inhaled after our visit.

On our recommendation he ate his breakfast with a view to satisfy his appetite,—a thing he did not dare to do the night before from fear of being too much oppressed.

After the repast he felt no more than the usual inconvenience.

The 27th he inhaled twenty-five litres of oxygen.

The appetite, a little increased, was again satisfied by the patient, who, on the 28th, announced to us that his breathing was no longer oppressed.

The asthma had disappeared.

[There is nothing instructive in this case, beyond the already established fact that oxygen inhalations will, in nearly

every instance, surely and promptly cut short a paroxysm of asthma when not too extensively complicated. It appears that the remedy was exhibited but twice, indifferently at that, in the five days' history of the case. In all, forty-five litres, or about twelve gallons, of the gas was used. What the result would have been, as to future attacks, had this patient been given eight, ten, or even twenty gallons per diem, is left to conjecture by the author.—TRANS.]

Case VII. Among the cases which it has been our good fortune to observe there has been one which was indeed very striking. It relates to a man who came under our care to be treated for a comminuted fracture of the thigh. This unfortunate man was asthmatic, and as he could not maintain the horizontal position he was compelled to pass the nights with the windows open and sitting up in bed. Oxygen ameliorated his condition but did not cure it. We then mixed a quart of carbonic acid with three quarts of oxygen, and our patient was cured; that is to say, the paroxysms of asthma ceased. This is not so surprising as it would seem, for observation teaches that paroxysms of asthma subside in certain individuals under the influence of keen air; others, on the contrary, prefer low and damp situations rather than high and open ones, the city to the the country, the stifling air of large crowds to that found in roomy apartments. This explains, also, the favorable results which have been obtained with pure oxygen, and with air mixed with hydrogen or carbonic acid.

Case VIII. We do not note in Hill's work a single case of the use of oxygen in the treatment of asthma, but he cites a case of nervous cough occurring in a young girl. Tonics and antispasmodics relieved it, after two months' treatment; but at the expiration of a month there was a relapse, with aggravation of all the symptoms. She was now treated by oxygenized air. At the end of fifteen days relief was almost complete, and three weeks later the cure was positive. The English author states that under the influence of this remedy the constitution of the child was much improved.

How shall we explain these facts? Is it by the direct action of oxygen, of hydrogen, or of carbonic acid on the bronchial mucous membrane that the paroxysm of asthma is interrupted or modified; or is it by the action of the gases on the central nervous system through the intermediation of the blood?

All these questions will no doubt one day be solved, but for the present it is only necessary to record the facts, and we challenge any explanation which is not the strictest deduction from direct clinical observation.

We do not find, in the table given by Beddoes, any cases of disease of the chest in which oxygen has been employed, during the time it was in use by this practitioner. Further on we will call attention to this fact. It is explained, however, by the failures and untoward results which had been experienced with it in the treatment of phthisis. In one place in his work he undertakes to explain the insufficiency, and even danger, of having recourse to oxygen [in phthisis] by the following theory: According to him, there is in consumptives hyper-arterialization of the blood; oxygen would, consequently, be in excess in the blood of these patients, and hence, according to him, it is best to avoid placing them upon the use of this remedy. Hence, Beddoes selected for his consumptives an atmosphere less oxygenated and less stimulating than the air of the country. However, we shall not admit the assumptions of the English author so long as they are wholly theoretical, and he himself had not, in his day, any scientific basis on which to support them. In fact, the gases of the blood, the existence of which was not then known, had, of course, not yet been made the subject of any careful analysis.

To-day we are aware, it is true, that the proportion of oxygen taken up by the blood is susceptible of variation; but, unfortunately, the circumstances under which these variations are produced are not yet determined with sufficient accuracy so that we can deduce positive indications. Let us hope that the advancement of chemical analysis will afford us new light on this subject. This seems to be assured, and any one who will study the subject as we have done will, perhaps, be convinced that there are a number of thoracic affections in which the use of oxygen ought to be proscribed, and particularly in acute phthisis, with fever; or even, whatever may be the form, when the disease has reached an advanced stage, since at such time any active excitement of the nervous or of the circulatory system may have a very unfavorable influence on the local condition; but at the outset of phthisis, in lymphatic or scrofulous individuals, when the symptoms are only slightly marked and the patient grows thin; and when persistent dyspepsia still further

increases the tendency to emaciation, and causes material, poorly elaborated by a deficient digestion, to further contribute toward an insufficient nutrition, and to the formation of pulmonary tubercles,—in these cases oxygen has given, and will give, good results. The fear that we might have, with regard to over-stimulation of the bronchial mucous membrane, ought to yield, in the face of experience. We have breathed oxygen, in the course of a bronchitis, without the least aggravation, and our friend, Dr. Foley, has given it in a case of phthisis to check recurrent hæmoptysis, with good effect. By this it is seen that it does not do to decide positively as to the action of oxygen from its chemical properties, as many learned men, whether chemists or physicians, have done. It is for experiment alone to decide; and, in a like issue, speculative and preconceived ideas frequently have no other effect than to divert from the real truth those who would gladly follow it.

We protest, then, against all exaggerated fear relative to the use of oxygen. We do not mean to say that oxygen, or any other gas, should be given unreservedly. Nor should we forget that in causing any one to inhale a gas, the circulatory medium is placed in contact with a new agent, which acts directly on the nervous system; and that the pulmonary mucous membrane, besides being organized for this purpose, is endowed with a power of absorbing, or rather with a permeability, as regards these agents, which is very remarkable. These considerations having been offered, let us scan the facts which alone, at this instant, should outweigh every mere speculation of the mind.

We have described, in the historical portion of this work, the attempts that have been made in this particular direction. The cases we have been enabled to observe are not numerous, but we can add to our personal experience that of the learned and discreet, M. Monod, and that of one of my most honorable *confrères*, M. Hervé de Lavaur.

Case IX. *Chloro-Anæmia* [*Tubercular?*] *Treatment by Oxygen.**—" S. P., aged seventeen years and nine months, complained of languor and general debility. She had palpitation and oppression on making the slightest exertion, especially in climbing stairs. She was pale and very much emaciated; for several months the feet and ankles had been afflicted with

* Beddoes, *op. cit.*, part i, page 74.

œdema every day toward evening, or after the least exercise. Gastric pains; frequent cough, accompanied at times by pains in the head; appetite impaired; pulse 112. The catamenia had never appeared, and the patient had never experienced the symptoms which usually precede this function. She began to complain about two years and a half ago. Since that time she has taken many remedies, but without any benefit.

"February 14, 1795, I prescribed for her a mixture of oxygen and atmospheric air, in the proportion of three to seventeen, to be inhaled daily.

"February 18th. This modified air has not yet produced any perceptible effects. I prescribed seven litres of oxygen, diluted with sixteen litres of common air.

"February 23d. Since the dose of oxygen was increased the patient does not rest well, and complains of a considerable degree of general heat. The cough has become more frequent; pulse 125. [Impure gas—in fact, *chlorinated oxygen*—was here, again, the cause of failure. The described symptoms evidently point to it.—TRANS.]

"February 26th. The nights are sleepless; the cough has increased; gastric pains remain the same; pulse 120 to 125. I prescribed again the diluted gas in the same mixture as in the beginning.

"March 1st. Nights quiet; sleeps; less burning heat; cough less frequent; gastric pains not diminished; pulse 110.

"March 6th. The patient suffers less in her stomach; she feels more appetite, and a much greater degree of strength; exercise causes less fatigue and dyspnœa; pulse 100.

"Her outward appearance is decidedly more encouraging; the cough is less frequent; less dyspnœa and palpitation; sleeps normally; œdema of the lower extremities does not reappear, except following unusual fatigue.

"March 15th. The general improvement continues; scarcely any cough; no more gastric pains for several days; so little dyspnœa and palpitation that the patient can walk two kilometres without strain, and almost without fatigue; pulse 89.

"March 20th. General condition much improved; the paleness has given place to the normal color; her cheeks, her lips, and her nails have resumed their rosy tint; pulse 81. Not the slightest symptom of the catamenia, but as this function is associated with a certain condition of tonicity of the arterial system

I have no doubt that it will appear when the health shall have become a little more fully established.

"March 28th. The general condition has continued to improve daily; the appearance of the patient is excellent and the strength good. JOHN CARMICHAEL.

"BIRMINGHAM, March 29, 1795."

Case X. *Tubercular Epididymitis; Phthisis Pulmonalis in the Third Stage; Respiration of Oxygen Gas; Remarkable Improvement.**—Mr. X., thirty-two years of age, entered the hospital, February 20, 1864. He was put to bed (cot No. 4, first male ward, on the second floor).

Toward the end of January last, after a very long tramp in the snow, this man was taken with a very severe pain in the right testicle. The organ gradually swelled and the skin of the scrotum became very red. He applied to a physician, who prescribed frictions with Neapolitan ointment, and applied poultices. This treatment having been followed for several days, and the tumefaction constantly increasing, Mr. X. decided to come to the hospital. The skin of the scrotum became of a reddish purple, the testicle increasing to the size of one's fist; tumor tense and indurated, pressure decidedly increasing the pain. Has never had a chancre, and there is no symptom of syphilis. He had blennorrhagia several months since, but to-day the urethra does not show the slightest symptom of discharge.

This man is very much emaciated. He is pale and anæmic; has coughed for a long time; has never had hæmoptysis. His cough is accompanied by expectoration of muco-purulent sputa, nummular, green patches, floating in the midst of a liquid resembling a solution of gum arabic. On percussion, dulness at the apex of the lungs, in the subscapular and subclavicular fossæ. On auscultation, on the right side, feeble vesicular murmur, but no abnormal sounds. On the left side anteriorly, gurgling sounds, pectriloquy in the subclavicular fossa; moist crackling in the subscapular fossa near the spine. High fever in the evening; a little diarrhœa for the last few days.

Treatment: Couch-grass tea; frictions to the testicle with Neapolitan ointment; poultices; Bordeaux, 250 grammes; second-grade diet.

February 25th. Applied a compound mercurial plaster to

* Case reported by Dr. Cosmao-Dumenez.

the testicle; pills of diascordium; bismuth and extract of opium; starch lotion. The diarrhœa is much more severe.

March 1st. The patient is placed upon inhalations of oxygen, four litres of the gas to ten litres of atmospheric air.

March 3d. The patient had yesterday a feeling of fulness in the chest. Half an hour after inhaling the gas he experienced some nausea and eructations; appetite no better; cough less frequent; expectoration less abundant; slept well last night.

Oxygen, twelve litres; no immediate change in the pulse; no flushing of the mucous membranes, after these inspirations. The patient demands food. Fourth-grade diet.

March 4th. Yesterday a little sleepiness during the daytime; less appetite to-day. Very little cough; no expectoration. Oxygen, twelve litres. Respiration appears to be deeper than in the first days. The pulse, a little irregular during the administration of the gas, recovers its normal condition after the inhalation.

March 6th. Voracious appetite yesterday; sleeps well; physiognomy better; general feeling of well-being; oppression much less. Oxygen, twelve litres.

March 8th. Cephalalgia yesterday; palpitations of the heart; sleep disturbed; fitful dreams. This morning the patient is much better. Oxygen, fifteen litres.

March 10th. The patient has been up for two days and walks about the house. His appetite is such that, after having taken a meal at the hospital, he dines a second time in the city. His countenance assumes color, and his cheeks fill out. Respiration is easier. The testicle has considerably diminished in size.

March 12th. A fluctuating point in the tumor of the testicle; puncture with the lancet; escape of nearly a teaspoonful of serum.

March 14th. The general condition is singularly improved; the appetite has much increased. Oxygen, fifteen litres.

March 16th. M. Cazalis, who saw the patient on his admission to the hospital, and who had discovered a tubercular cavity of the size of a hen's egg in the midst of hepatized lung-tissue, the apex of the left lung no longer performing its function, examined him to-day and ascertained that the cavity still remains, but that the surrounding tissue, which had lost all respiratory action, is now performing its functions fairly well.

The patient finds, moreover, that his inspirations are deeper,

his lungs more free. He went out again yesterday and walked half an hour. He has considerable appetite, and says he will be obliged to ask for a regular supply of food [full diet] if we continue to give him oxygen. His digestive and circulatory functions are normally performed.

His countenance is no longer that of a consumptive. The testicle has much diminished in size; it is softer and less painful.

Ordered to continue the fifteen litres of oxygen; cinchona wine; syrup of iodide of iron.

March 18th. A slight hæmorrhage from the mouth or fauces, after inhaling oxygen. [An unheard-of accident in American practice.—Trans.]

March 19th. The appetite continues to increase; the strength has returned to such a degree that the patient can walk to the Batignolles. He sleeps well, but dreams at night.

March 20th. Another slight hæmorrhage after taking oxygen.

March 26th. The patient, henceforth, is directed to respire thirty litres of oxygen. After the inhalation, vertigo, and sensation of a net-work before the eyes. The cough and expectoration have been completely suppressed. No gurgling is heard over the region where it was detected a month ago, but still there is pectriloquy, and the respiration assumes something of an amphoric character.

March 30th. From this time, at the request of the patient, the oxygen will be divided into two doses, of fifteen litres, morning and evening, the appetite being too much increased in the morning (by the thirty litres).

The patient continued thus to inhale oxygen during the entire month of April. His health became quite satisfactory. He was determined to leave the hospital the 29th of April, when he discovered, in the morning, small, subcutaneous ecchymoses, resembling patches of purpura; the general condition being good.

April 30th. The patient leaves the hospital, in the most satisfactory condition.

Case XI. *Report of Pulmonary Phthisis Treated and Happily Benefited by Inhalations of Oxygen.**—" Mme. de B., residing at Paris, suffering from phthisis pulmonalis in the third stage, was, on the 1st day of March, 1864, placed upon inhalations of

* Case reported by Dr. Cosmao-Dumenez.

oxygen gas. This lady, twenty-seven years of age, had experienced numerous recurring and severe hæmorrhages, during the preceding year. Since then she has continually coughed, and her general condition has been so bad as to necessitate her removal during the preceding winter to the South of France. There she had been subjected to the treatment of residence in a dense atmosphere, but without obtaining any noticeable amelioration.

"At the time when we were called to examine her she was found in a state of considerable distress. The cough was extremely frequent, especially at night, accompanied by an expectoration of characteristic, nummular, and opaque sputa, floating on the surface of liquid mucus. The appetite was next to nothing. The pulse was at all times rapid; night-sweats very profuse. She had no diarrhœa. On percussion of the chest we discovered on the left side absolute dulness of the upper two-thirds of the lung. On the right side we noted the same symptom in the subscapular and subclavicular fossæ. On auscultation we found gurgling and pectriloquy. On the right some subcrepitant râles.

"With this combination of signs there could be no doubt as to the diagnosis.

"All other treatment was suspended, and Mme. de B. inhaled, morning and evening, five litres of oxygen, mixed with an equal quantity of air.

"The first two days there was no change. The patient experienced only a sensation of warmth in the chest immediately after the inhalations. The dose was increased, the patient inhaling seven litres of the gas morning and evening, adding to the container at least three litres of atmospheric air. This time the sensation of warmth experienced was much more marked; the appetite improved a little; the general condition was more satisfactory. Meanwhile, in the middle of the night, during a fit of coughing, a sudden pain was felt in the left side of the chest, and the patient expectorated matter streaked with blood. On examination the next day, with M. Roudet, her usual medical adviser, we discovered on the left side, on percussion, excessive resonance; at the same time, on auscultation of the voice, considerable increase of the previous pectriloquy. Finally, on causing the patient to cough, we noticed, at each shock of the cough, the sound of metallic tinkling.

"A pneumothorax had occurred.

"Nevertheless, the condition of the patient being quite satisfactory, the inhalations of oxygen were continued, reducing the dose, however, to five litres, night and morning. The bloody streaks in the sputa rapidly disappeared, and little by little, the patient, who was able to partake of a good repast, night and morning, gained sufficient strength to arise and walk, in her room, for three or four hours daily. The gas effused within the pleura was re-absorbed, little by little, and in auscultating it, ten days after the advent of this complication, we did not find such marked pectriloquy, nor the metallic tinkling which previously existed. The general condition appreciably improved from day to day, and the 27th of May,—that is to say, on the twenty-seventh day of her treatment by oxygen,—Mme. de B. found herself strong enough to give a dinner at her residence, and to do the honors at table for her invited guests, for two consecutive hours.

"After this the patient was able to pass the entire day sitting up, and to go out in a carriage. The 1st of June she left for the country, where she continued her oxygenated inhalations. We had opportunity to visit her there at various times. She was taking frequent walks in the garden, breakfasting and dining at table. In short, excepting the cough and expectoration, which, although less frequent, still persisted, this patient presented, as compared with her former condition, the appearance of a very fair state of health, a truly remarkable result. Menstruation, which had not occurred for five months, reappeared at the end of June.

"The vacation period arriving, we for some time lost sight of the patient, and, in spite of the efforts of the members of her family about her, she left off the oxygen inhalations early in September. The general condition still remained satisfactory for some time, but with the first fall rains the cough returned with renewed activity, expectoration became abundant, fever reappeared, appetite diminished; in short, all the symptoms so significant of the third stage of phthisis assumed a fresh intensity, and when we saw the patient, on the 20th of November, she had relapsed into a condition of great feebleness and emaciation. She reverted from time to time to inhalations of oxygen, but she was discouraged, and took her treatment in a very irregular manner. Colliquative diarrhœa was not slow to

set in; the patient reached the lowest stage of decline, and succumbed on the evening of February 28, 1865."

Case XII. *Phthisis Checked by Oxygen*.*—"Mr. G. B., thirty-five or thirty-six years of age, born at Buenos Ayres, of a father dead of phthisis, and of a mother who has a vigorous constitution, and is enjoying a really excellent degree of health; has always been of a weakly constitution and excessively nervous. Residing in Paris since his youth, he has experienced for ten years past the primary symptoms which lead to a suspicion of tuberculization of the lungs. Since that period the disease has been slowly developed. Several courses at the springs of Mont-Dore, and numerous sojourns in the south during the winter, have not moderated the progress of the disease. During the last few years very abundant hæmoptyses have occurred. M. Boudant, of Mont-Dore, and M. Barth, of Paris, had, like myself, detected the existence of several cavities and numerous tubercular patches, especially in the right lung. The last hæmorrhage took place in the winter of 1864. The patient was considered too weak to be sent south, and remained in the city, confined to his room. Subsequent to this last hæmorrhage he declined quite rapidly. In the spring of 1864, he was carried to the country, at Margency. Having been called to see him, I found him in such a condition as made me fear he would not see the end of the year. The pulse was habitually rapid; there was the evening exacerbation of fever, with chill, heat, and sweating; expectoration abundant and muco-purulent; utter lack of appetite, and such debility that the patient did not leave his bed, except to be moved into his invalid chair. I advised inhalations of oxygen. The immediate effects were such that we were inclined to hope that in the valley of the Montmorency the patient might eventually recover. He did recover his appetite and strength to such a degree that he could walk in the garden, and from time to time came to Paris to attend to his business. From this period, that is for six months, Mr. G. B. inhaled, night and morning, twelve litres of oxygen. He spent the last winter shut up in his Paris residence, and returned in the spring to the country, from whence he made frequent trips to Paris. He had no more hæmorrhages; the cough became rare, and expectoration insignificant; appetite uniformly good. And yet the malady was undoubtedly

* Report furnished by M. Monod.

making insidious progress. The pulse was always rapid, and his strength much less than formerly. It was evident to me that oxygen had not cured the patient, but it had interrupted the progress of the disease, which last spring appeared to have reached the end of the last stage; and this improvement so closely coinciding with the use of oxygen, we cannot help attributing it to the use of this gas."

Here, again, we have the opinion of our distinguished *confrère*, M. Hervé de Lavaur, as to the opportuneness and efficacy of oxygen in phthisis, in some unpublished notes which he has kindly placed at our disposal:—

"I have had but nine patients who have been treated, in a measure, with oxygen inhalations. Among this number were three cases of remarkable success:—

Case XIII. "The first was a consumptive of long standing, having enormous cavities at the apex of one lung, and who, at the time I prescribed the inhalations, had the most copious expectoration, evening fever, frequent cough, a dyspnœa which rendered the least exertion tiresome, and, lastly, a total lack of appetite. Inhalations of oxygen were prescribed to the extent of fifteen litres per day, at two intervals, diluting the gas one-third with common air. Gradually the quantity of gas was increased to forty-five litres per day, taken undiluted, and at two doses during the day.

"Under this treatment, expectoration ceased, appetite revived, and the patient promptly became convalescent. The gas was continued during nearly three months, the dose being gradually diminished; and now for about five months the patient has gained in flesh, resumed his ordinary occupation, and continues as well as could be asked.

Case XIV. "In case of a second patient who was placed upon oxygen inhalations, there were crepitant râles over almost the whole extent of both lungs, crackling at the apices, frequent cough, copious expectoration, and a terrible dyspnœa, which compelled him to pass the greater part of his nights in his arm-chair.

"There was a consultation, and two of our most eminent practitioners rendered a most unfavorable prognosis. The patient went from bad to worse, until, finally, the appetite was entirely wanting. I prescribed inhalations of oxygen. At the end of three days the patient refused to continue them, alleging

that it fatigued him, and that the remedy did him more harm than good. Such was not my opinion. I had noticed a little diminution of the dyspnœa and slight evidences of returning appetite. I, however, yielded to the whim of the patient; the inhalations were omitted; but I decided to return to them after five or six days, and this time they were kept up regularly for about a month. The dose of gas was, at first, fifteen litres, mixed with air; afterward increased to twenty, thirty, and forty-five litres, without any dilution. Under this treatment improvement was rapid, dyspnœa disappeared, appetite returned; and the patient is now actually as well as possible, attending to all his engagements, and asserting that he was never in better condition."

Case XV. "The third was a patient having tubercular deposits at the apices of both lungs, and having also a hypertrophy of the heart, violent palpitations, and a dyspnœa which prevented him from taking the least exercise. He was placed, for about a month, upon inhalations of oxygen. The cough diminished; his appetite—which was *nil*—and his strength returned, and at the end of three weeks the patient was able to take long walks, without causing dyspnœa or fatigue.

"With the other patients the results were much less satisfactory. Three of them, cases of phthisis with cavities, experienced some improvement, and three others were not benefited, without my being able to discover, in the condition of the patients, the reason for this difference in the results obtained. I do not refer to patients who, having tried the remedy for a few days, did not continue it. I might also add that in the case of all patients who used the inhalations, oxygen was not exclusively employed; and that during the whole time of treatment the patients continued the use of quieting syrups, cod-liver oil, etc.; and with nearly all I have prescribed revulsives to the surface, croton-oil, blisters, etc.; nevertheless, I am convinced that the recovery, or rather the decided improvement which followed, in the case of the first three patients, was wholly due to inhalations of oxygen."

Doubtless these facts are insufficient to determine the curability of phthisis by inhalations of oxygen; but such as they are they are sufficient to show the benefit which may be derived from this remedy. We have again, a few days since, seen our first patient. He remains in good health. The lesions

occasioned by the softening of the tubercles of the epididymis are healed, and nothing in his appearance would suggest any suspicion of the grave disease with which he was afflicted. If it is true that pulmonary phthisis is often merely the symptom of a general condition, with special manifestation in the lungs, nothing is more rational than to believe that oxygen, this chief modifier of nutrition and of the organism, is capable of improving, in certain cases, the constitution, and arresting the progress of the disease. Furthermore, if physicians enter upon this line of inquiry, it will be necessary to determine at what period of the disease it will be advisable to adopt this treatment, and also the varieties to which it is more particularly applicable. For our own part, we believe that oxygen is competent to render great assistance to consumptives, at the beginning of that period which we will call the dyspeptic stage, when the patients cough but little, grow thin, have no relish for food, and are suffering from difficult or imperfect digestion. It will also be found more efficient in case of lymphatic individuals, even when the disease is confirmed. In this case, also, as is proved by the foregoing facts, we can restore the strength and combat the disease. We have prescribed oxygen in three cases of phthisis far advanced; in one case the results were *nil;* but in the two others there was a notable improvement in the strength and appetite; the sputa and the night-sweats were much diminished. In one case, which occurred in a poor woman who was both consumptive and diabetic at the same time, the improvement was such that her family believed she would recover. We were obliged to negative the too ardent hopes of this interesting family, in order to prevent a too severe disappointment. Finally, these two patients succumbed, by a slow decline.

We have administered oxygen not only in asthma and phthisis, but also in a case of bronchial dilatation; and if in this condition oxygen has not effected a cure, it has decidedly modified the general condition, as will appear from the following case :—

Whereas Dr. Birch lauded the use of oxygen in congestions in general, we will add as our estimate that it ought to be successfully used in dilatation of the bronchia. We know, in fact, that in these cases hæmatosis ought to be very difficult of accomplishment. The physiological conditions favoring respiration are wanting, or rather are weakened; further, the air

must with greater difficulty penetrate throughout the entire bronchial system. In this condition oxygen ought to act, first, in a direct manner, stimulating the bronchial contractions, and, second, as favoring hæmatosis. These results, moreover, seem to us to have been realized in the case which we here publish.

Case XVI. *Report of a Case of Bronchial Dilatation Favorably Modified by Inhalations of Oxygen*.*—"Mr. S., banker, residing in Paris, was, on the 15th of May, 1864, placed upon inhalations of oxygen for a chronic affection of the respiratory passages. He had coughed for several years, the cough being not at all painful. It increased in frequency, particularly in the morning and evening, and was accompanied with an expectoration of greenish, opaque, nummular masses, adherent to the bottom of the vessel, and about the size of a five-franc piece. Respiration was generally somewhat difficult, but not so during periods of fogginess, or when there was both cold and dampness. Appetite very slight. Mr. S. had grown remarkably thin, since the commencement of his trouble. On auscultation we found mucous râles scattered here and there over the chest, but especially at the base of the right lung. Percussion, however, revealed no change in the normal resonance of the chest.

"Mr. S. presented no family history which would arouse in him suspicion of tubercular disease. He had a large family of children, and all were in good health. Never had a hæmorrhage; no night-sweats.

"Taken as a whole, these symptoms, and particularly the character of the sputa, led to the belief that Mr. S. was suffering from bronchial dilatation.

"May 10th, he inhaled five litres of oxygen, morning and evening, mixed with an equal quantity of air.

"He experienced, during the first inhalations, a lively sensation of warmth in the chest; otherwise nothing in particular was noticed, on the part of the organs of sense, or of the digestive organs.

"The 11th, 12th, 13th and 14th the patient continued the inhalations, and gradually increased the dose from five to six, seven, and finally to ten litres, morning and evening. He then experienced a sense of vertigo immediately after inhaling, and there was a slight numbness of the hands and feet. This soon disappeared, and the patient experienced, after a little time, such

* Case reported by Dr. Cosmao-Dumenez.

a marked sensation of hunger that he was obliged to eat two or three times between meals. He observed, at the same time, that his cough became less frequent, expectoration was thinner and less copious, the general condition was improved, and Mr. S. began to gain a little flesh.

"From the 14th to the 18th of May we did not see the patient, who, however, continued the inhalations, in doses of ten litres of pure gas, morning and evening. The sputa, before greenish, had become almost white, and the appetite was excellent.

"Mr. S. then left for Soudon, where he continued the inhalations for several weeks, all the time realizing from them great benefit. We have now for several months entirely lost sight of him."

Case XVII. Beside this case we will place the following, which to us appears to be no less interesting. It is the case of a young woman presenting enlargement of the glands of the axilla, the neck, along the trachea, and probably of the bronchia. She came into our service for the purpose of having tracheotomy performed. Under the influence of oxygen her condition was at once improved, and she left our service, not cured, but in a condition which enabled her to come and go at will, and to engage in her usual occupations.

Some of the unfavorable symptoms recently reappeared in her case under the influence of cold and privation. Again, oxygen caused dyspnœa to disappear, and her condition quickly improved.

Case XVIII. *Tubercular Swelling of the Neck; Compression of the Respiratory Passages; Threatened Asphyxia.**—Mrs. S., aged thirty-five, entered the Municipal Hospital, March 14, 1865.

This woman menstruated at fourteen, and menstruation has since been regular. She is the mother of one child, five years old to-day, which is now healthy, and has always been of very good constitution. Interrogated as to her antecedents, she replies that her father and mother have always enjoyed excellent health. As to herself, she says that her health has always been excellent. When a child she had, in the cervical region, some swollen glands. On the left side, behind the angle of the jaw, she has some scars which apparently might have resulted from incisions made for the relief of suppurating glands.

* Case recorded by M. Boucher, interne.

The enlarged glands which she had in her youth disappeared, so to speak, at the dawn of puberty; but about six years ago, or, in other words, about the age of twenty-eight or twenty-nine years, there appeared, in the subclavicular fossa of the left side, a swollen gland which became quite large, but which afterward rapidly and almost completely disappeared.

Three years later, other enlarged glands appeared in the left axilla; subsequently numerous glandular swellings occurred in the right subclavicular region. On her admission to the hospital we found her condition to be as follows: Four or five small indurated glands in the left axilla; one of these, which impinged a little upon the mammary region, was nearly as large as a pigeon's egg. In the right subclavicular region there was a circle of enlarged glands of small size. All the tracheal glands which could be explored by palpation were enlarged and indurated. On the left of the trachea, in the cervical region, there was quite a mass of enlarged and indurated glands (ganglions), which compressed the passage and caused it to quite perceptibly deviate toward the right.

Two months before this patient entered the hospital, respiration was still normal; but for some days past respiration has become very difficult; the patient pants, making at times strong efforts to inspire, as though to overcome an obstacle to the free entrance of air. If she walks a little too much, or if her step is a little too rapid, her breathing becomes still more difficult. In a word, she *wheezes* when she walks. At times there are veritable paroxysms of suffocation. The latter, which sometimes occur spontaneously, manifest themselves more especially after a walk a little too hurried, or it may be after a meal. Respiration is accomplished much easier when the patient is in bed. When she is on her feet it is sibilant and painful. On percussion, the chest shows normal resonance; on auscultation, there is everywhere heard somewhat harsh respiration, with some blowing sounds, due, no doubt, to compression of the bronchia. The patient was sent to us for the purpose of having tracheotomy performed; but there was certainly no ground for practicing this operation, since compression exists, not only at the level of the cervical region, but unquestionably extends to the trachea, and probably to the bronchia. The only treatment to be used is a general treatment capable of acting on the nutrition, and favoring resolution of this general glandular engorgement.

We gave this patient a tonic treatment, and at the same time caused her to inhale each morning fifteen litres of oxygen. We continued this about a month. The appetite increased a little; some of the glands diminished in size; but when the patient was out of bed her respiration was always painful and whistling. Paroxysms of suffocation, it is true, were less frequent, but occurred from time to time.

We doubled the quantity of oxygen, that is to say, we caused her to inhale, morning and evening, fifteen litres of this gas, mixed with an equal quantity of air. After five or six days of this treatment we noted a considerable increase of appetite, so much so that the patient was obliged to eat during the night, and several times during the day, between meals. At the same time the complexion improved; the skin and mucous membranes regained color. We were soon able to note, also, a perceptible diminution in the size of the enlarged glands. The large group which compressed and deflected the trachea became softer, somewhat less in size, and more mobile. Her breathing at this time was normal when the patient remained in bed, but was still somewhat difficult when she was on her feet; but we no longer heard the painful wheezing which previously existed. There were still, from time to time, some paroxysms of suffocation, but they were less persistent and less pronounced than formerly, and walking was less difficult.

We continued thus to give this patient thirty litres of oxygen per day. The remarkable thing in connection with this case was the extraordinary appetite of the patient. The improvement continued every day, from this time, and she left the hospital on the 26th of May.

It would seem to be rational to try inhalations of oxygen, following tracheotomy, performed in cases of croup,—first, to resuscitate the patient, and, second, to modify the blood itself. In one case, where a blister was followed by a coating of diphtheritic membrane, and the child was pale and disinclined to take any nourishment, oxygen inhalations, repeated four or five times a day, two to four litres each time, mixed with a certain proportion of air, we found to be very beneficial to the child, which made an excellent recovery. With another the result was not so fortunate. The child died.

Our friend, Dr. Foley, used oxygen in the course of a typhoid fever. We are aware that the action of this agent on

the blood, the tissues, and, secondarily, on the vasomotory system, is capable of rendering great service. In certain cases we have succeeded in modifying congestions and combating gastro-intestinal pneumatoses; even more, oxygen will overcome the blood-poisoning of patients suffering from this latter disease. We have seen, in speaking of carbonic acid gas, all the conclusions which English physicians of the last century have deduced from a study of this agent. Perhaps, by a combination of these two gases, we might often favorably influence the course of this disease. We publish the case of Dr. Foley without comment. It is, however, accompanied by very judicious remarks, which are worthy of careful consideration.

Case XIX. "Mr. Y., a small, active man, possessed of perfect health, accustomed to feats of extraordinary muscular exertion, and having great intellectual strength, did not leave his office-work except to visit his yards, or to make long journeys, scarcely taking time to eat or sleep, until he was completely jaded.

"After several years of such habits he became sick and applied to me. At the time, he showed only the symptoms of a curvature, complicated with hepatic congestion, derangement of the stomach, persistent constipation, cephalalgia, nausea, etc. Evacuants afforded a temporary relief; but the rest recommended (above everything, and under pain of an attack of typhoid) was neglected.

"Mr. Y., from feeling some better, began again, just as though he were in the best condition. Eight or ten days afterward, the predicted disease forced him to bed.

"The cerebro-spinal symptoms were not severe; dilirium not excessive; the muscles, strongly contracted, showed no very prominent nodosities, nor were they difficult to make disappear. Stripes made by pressure upon the skin were not slow to resume color, nor were they very long in being effaced.

"From its first appearance tympanitis was extremely severe. The abdominal walls, and especially the intestinal muscular tunics, lacked strength. The evacuations, both liquid and gaseous, neither very copious nor very fetid, were very hard. Neither all the known tonics, nor all the astringents, could overcome the meteorism.

"The characteristic cutaneous patches were very numerous, scattered all over the body, appearing slowly, and very slowly

disappearing. Notwithstanding the patient was nourished as much as possible, this adynamic feature of the case was quite persistent.

"At length, improvement was announced. Suddenly a paroxysm of intermittent fever developed, with symptoms of hepatic congestion. Quinine was without effect. I then gave oxygen; and very quickly the periodic stages abated; then disappeared. The skin, which was so spotted, did not assume that gray tint, pale and earthy, nor that nauseous odor, nor the dry touch, snapping and hot, which it shows in so many invalids."

What does this record indicate to us?

A man who is jaded out, wasting flesh much more rapidly than he can rebuild it, devitalizing his blood, his tissues, his interstitial fluids, beyond measure, is attacked by a hepatico-intestinal congestion, suddenly complicated with typhoid poisoning.

The viscero-abdominal derangement, the first to be observed, and the first treated, yielded a little; but the bad hygienic habits were resumed, all tending to increase the blood-poisoning. Very soon this latter condition overshadowed the local one, the greater masked the lesser affection, pursued its course, sharply accentuated its primary character, and then its secondary.

After the depuration of the miasma (produced, perhaps, within the organism itself, at the time of its hyper-physiological impulse,) had been accomplished, the general pathologic condition improved; and the local lesion, temporarily obscured, resuming its original importance, betrayed itself by periodic paroxysms.

Then, seeing that quinine, administered to an organism which neither performed its functions nor assimilated well, produced no effect, we resorted to oxygen.

The following report of Hill's serves to corroborate the above. It is especially remarkable from the fact that this author has so thoroughly witnessed the part that oxygen plays in so many of these cases, administered as a therapeutic agent, to wit, as a general modifier, stimulating and reviving the organism to such a degree as will render it more susceptible to the action of remedies, and will enable the latter to exercise all their curative influence.

Case XX. *Intermittent Fever Treated by Oxygen.**—"Mrs.

* Hill, *op. cit.*, p. 32.

Priest, a woman of weakly constitution, was attacked in August, 1795, in the county of Essex, with an intermittent fever so severe in character as to put her life in jeopardy. The interval between the paroxysms was so short that no remedy was capable of interrupting them. Cinchona, mercury, balsamics, a change of air, and other remedies advised by various physicians and followed for nearly three years gave no relief, and the disease assumed the form of a tertian fever, which so exhausted the patient that she was compelled to keep her bed almost constantly. To this general weakness was added considerable enlargement of the spleen, so that this organ occupied the whole of the left side of the abdomen, and by compressing the vessels behind it caused an œdema of the lower extremities. At the outset the disease was accompanied by jaundice, and when I saw Mrs. Priest, in 1798, she still showed signs of engorgement of the liver. Finally, the jaundice persisted for an entire year.

"Under these circumstances I had great difficulty in finding any effective therapeutic means. Meanwhile, I prescribed vital air, hoping to impart to the organism sufficient vigor to enable me to cure the patient by the use of tonics. At the end of six days administration of the gas (one litre, to forty of air),* I had the satisfaction of seeing the paroxysms become less violent and shorter, and at the same time the inhalations of vital air had restored warmth and moisture to the skin, and ability to sleep. By gradually increasing the proportion of oxygen the symptoms were abated. Thanks to this treatment, aided by iron and mild cathartics, the patient was in a month restored. The general condition became excellent; the size of the spleen seemed to me considerably diminished, although I did not attach much importance to this. I know, however, that subsequently it entirely disappeared.

"Thus, while it was a bad quality, a specific state of the air in Essex, which caused the disease, it was pure air which cured it."

If it is true that intermittent fever is due to paludal miasmata which are absorbed into the blood, it would be equally rational to suppose that oxygen would exert a favorable influence, whether as a direct and unique factor in the treatment, or

* The dose in this case would strike a modern experimenter as fairly homœopathic, but I am convinced that very often better results are obtained by the use of diluted oxygen than from the pure gas. I would not, however, advise the extreme dilution practiced in this case.—Trans.

merely as an adjuvant. It is for this reason that we thought the foregoing case worthy of being quoted. In corroboration of this view, we recall the reports made by M. Foley upon workmen engaged in the construction of tubular bridges. *It followed from these partial studies that men who worked in compressed air were less liable to contract intermittent fever than those who worked on the banks of the stream.* This phenomenon deserves to be more conclusively proved. If, in fact, it is absolutely true, is it not an additional evidence that, in order to fortify ourselves against certain epidemic influences, we must render the air of our dwellings more highly oxygenated?

The blood is the regulator of the nervous system. According to this theory it was correct to endeavor to quiet certain disturbances of the nervous system by introducing into the blood a larger proportion of oxygen. In fact, to change the condition of the blood ought, naturally, to induce a change in the vital condition of the central or peripheral nervous system. This is what Beddoes, and, after him, Hill and Birch, effected. Beddoes reported that a young woman, afflicted for a long time with an obstinate headache, which had deeply affected her health and exhausted her strength, was promptly cured by the use of oxygen, in doses of twenty-seven litres *per diem* ; also, the case of a young lady in whom facial neuralgic pains had resisted every kind of treatment, but which promptly yielded to the use of oxygen. We have but once had recourse to oxygen to quiet neuralgic pains, which recurred every day at the same hour, in case of a very decidedly lymphatic woman. This woman, aged about forty-one years, returned from the South about eighteen months ago. While there she was seized with migraine, complicated with neuralgic pains, which finally resulted in a daily recurrence at the same hour. The paroxysm began about two o'clock and did not disappear until the next morning. This woman was pale, emaciated, and without strength or appetite. We placed her at once upon oxygen. The quotidian cephalalgia quickly disappeared, and our patient recovered her strength and appetite. Since that time she has remained quite well. There was a single recurrence of the pains, and then she immediately returned to the use of oxygen.

We are not the first to think of treating migraine with oxygen. M. de Lapasse, a man of the world, somewhat versed in medicine, extolled this means of combating migraine. We are

convinced that this remedy can be made to render some service in this disease, especially with women who are more or less chloro-anæmic.

We have seen, in our study of the gases of the blood, and especially of the physiologic action of oxygen, that in some way the muscles more particularly absorb this agent. We have seen that animals (pigeons or rabbits), which we have placed in oxygen, have had their muscles very strongly injected with highly arterialized blood. Is it this circumstance which has guided those physicians who, before us, have given attention to the study of the action of oxygen? We do not know; but it is very curious to note that all of them have recorded cases of paralysis cured by oxygen. There is no doubt but that, with certain persons, oxygen arouses a demand for muscular activity. This indication, on one hand, and the anatomical [physiological?] fact which we have above referred to, prove the powerful effect of oxygen on muscular action. The fact that paralyses have been cured under the influence of oxygen goes to prove the correctness of this view. But, we ask, what are the paralyses which have yielded to the influence of oxygen? Here it is necessary to acknowledge that accuracy is wanting in these cases, so that we will omit their reproduction. All the time, we very well know that in paralyses resulting from a toxic action, as from charcoal fumes, for example, or those, again, in which great debility of the system was a serious obstacle to the recovery, oxygen alone, or combined with other agents, and electricity, that other stimulant to the nervous system and the muscular circulation, will bring about very good results.

Many other affections, as shown by an examination of the table which we heretofore cited, have been treated by oxygen, but, not having had personal experience in this direction, we leave to those who are more competent, the responsibility of pursuing these investigations. Our end will be attained if we are successful in attracting attention to certain medical affections, in the treatment of which oxygen has unquestionably proved, in a more or less marked degree, efficacious.

III. APPLICATIONS TO SURGERY.

(*a*) Local Application of Oxygen.—The application of oxygen to a sound or diseased limb presents no more difficulty than the inhalation of the same agent, thanks principally to the

zeal and ingenuity displayed by M. Galante in the manufacture of apparatus adapted to the administration and application of the gases. To this end we have had made vulcanized rubber boots, or hoods, in which we encase the member, bands of diachylon-plaster affixing the upper opening of the same very tightly to the limb on which we desire to operate; a special tube connecting the interior of the hood with the external air, and serving to conduct the oxygen from the generating apparatus to the inside.

The patients on whom we at first operated not having experienced any sensation, one of the pupils in our service very kindly volunteered to make a series of experiments on himself. The temperature of one of the lower extremities was carefully taken; the latter was then placed in a boot (see cut), and

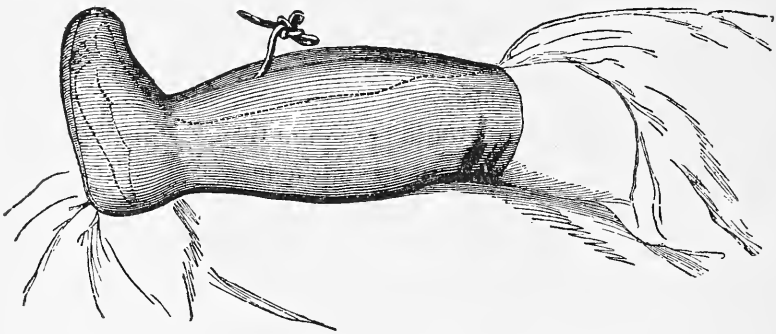


Fig. 6.—Rubber Boot, or Hood.

oxygen was introduced. The contact of this fluid at first produced no very distinct or appreciable sensation, but, at the end of an hour, when we removed the apparatus, we found at one time two-tenths of a degree of elevation of animal temperature, and at another time six-tenths; also a certain moisture of the encased member from the condensation of sensible and insensible perspiration. The elevation of temperature mentioned should be entirely ignored, since by the application of a hood or muff filled with common air, repeated at two different times, an hour each time, we obtained, in one experiment, an elevation of one degree, and in the other 2.2 degrees. It follows, therefore, that atmospheric air confined in a hood encasing a healthy limb will cause a greater elevation of the temperature than oxygen gas, similarly applied.

We report this fact, *en passant*, without attaching much importance to it, since we know that the temperature of a limb may fluctuate under various changing conditions, of which it is not always easy to take account.

Meanwhile, has oxygen any chemical effect upon the member to which it is applied? This, it does not seem to us admits of any doubt; for if we cause oxygen, which has been kept in contact with the body, to pass through lime-water, the latter is perceptibly clouded. There is, then, an exhalation of carbonic acid,—a phenomenon which was also observed by Abernethy.

But evidently other phenomena must be produced which we are not able to detect, but which intelligent chemists will not fail to bring to light. The physiological proof which must be forthcoming in connection with these tests, as a series of chemi-

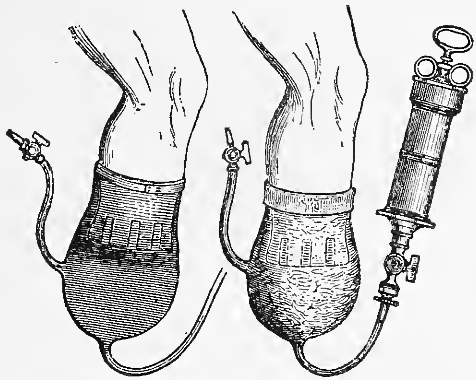


FIG. 7.—MUFF.

cal phenomena important to be understood, is that under the influence of oxygen we see congested parts very favorably modified.

We have often noted this fact in the case of senile gangrene in which the local congestion, bordering the gangrene, promptly changed its appearance.

Oxygen, as applied in several cases of eczema rubrum, which had advanced to the chronic stage, has quickly blanched the skin and legs, which were the seat of the morbid condition. Here is a fact well worthy of consideration, and to which we call the attention of chemists and dermatologists. It is, therefore, for the reason that we have been struck with these results that we have further applied oxygen to several limbs affected with varicose veins, with redness and alteration of the

skin, complicated with a condition of pronounced rigidity. Well, under the influence of oxygen, and of the exudation of fluids which follows its application, we have seen the condition of these patients rapidly improve. Admitting that we have not cured the varicose veins, we have quite promptly relieved the complications which accompanied them. We have now one patient still under treatment.

Applied to wounds, oxygen must be studied from the point of view of its effects upon old atonic ulcers, and upon recent wounds of benign character.

As regards the former variety, oxygen, less than carbonic acid, has induced a degree of non-painful excitation which may be made salutary. About two years ago, we had the case of a law student who had a large syphilitic ulcer, which had invaded the calf of the leg. It made walking difficult, not to say impossible. Careful treatment, continued for a long time, availed nothing. The same treatment, seconded by oxygen, locally applied, effected a cleansing of the ulcer, which ceased to present a grayish appearance; its edges subsided, and the young man recovered. What was the rôle of oxygen in this case? Was the cure of this extensive ulcer due to the influence of diet, to the sojourn in hospital, or to the effects of oxygen? This, perhaps, is difficult to determine; but we certainly know that a malignant ulcer may be profoundly changed by contact with vital air, continued for several hours per day. There is, as we shall show further on, independent of chemical influence, a special stimulation, on which we shall lay much stress.

Oxygen applied to a recent wound is not painful. It produces a little warmth, but it has by no means the stimulating action of carbonic acid, as we have several times observed after more or less severe operations on the hand or foot. These members placed for a longer or shorter period in contact with oxygen do not exhibit any special phenomena. It is especially useful in case of amputation of a finger, or the extirpation of an ingrowing nail, that we have been enabled to observe these results. We might say as much of its action on inflamed wounds. But if the action of oxygen is continued without intermission; if, for example, in case of a simple ulcer of benign character, we make daily local applications of free oxygen, this is what occurs: After the oxygen has remained in contact with the wound, for one hour or several hours, we observe that the granulations

are soft and red, but have a tendency to assume a grayish appearance; and that they become, as it were, folded upon themselves. The ulcer is covered with purulent but not very abundant serum. The pus examined under the microscope presents no unusual characteristics, but the day following this experiment the excitement becomes so great that it is absolutely necessary to stop the applications of gas, as is verified by the following report. It is evident that in this case there was a physio-chemical action on the part of the applied oxygen; but what physio-chemical phenomenon was brought about by its contact with the exceedingly vascular granulations? This it is impossible to determine, notwithstanding the importance of the question. Is there, as in the lungs, absorption of oxygen and exhalation of the other gases of the blood? And in what proportion is oxygen absorbed? These are points on which we are not informed. But it is very evident that oxygen causes in the wound a reactionary effort which may soon become a true inflammatory process, as the subjoined case tends to show:—

Case XXI.* Georges B., nineteen years of age, an employee, residing in Paris, having a good constitution, entered the hospital the 1st of April, 1863, for the purpose of securing such surgical attention as his condition demanded.

March 31st, this young man was thrown from a carriage and had his leg crushed between the wheel and the sidewalk. It was so severely contused that it was impossible for him to walk. Brought to the hospital, we found, in his case, a very severe contusion of the posterior portion of the right leg. It was not fracture, but maceration of the soft parts, and there was considerable oozing of blood. Twelve days later an abscess was freely opened. Suppuration, at first copious, diminished little by little, until toward the end of April, when we had before us a wound of very healthy aspect, situated just above the external malleolus, elliptic in form, and measuring eight centimetres in length by six in breadth.

For several days we applied an India-rubber boot inflated with oxygen. The results obtained were very nearly the same after each application. They are here given as recorded from day to day:—

First Application (*April 28th*).—Nine o'clock. The wound presents a rosy appearance. Granulations slightly developed. The

* Reported by M. Meric, hospital externe.

lower and external surface of the leg is found to be partly denuded. Ten o'clock. After having removed the limb from the apparatus the wound was seen to be enveloped in a thick layer of serum or lymph, and its color was a pale red.

Second Application (*April 29th*).—Ten minutes after nine. The appearance of the wound is much changed from that of yesterday. Instead of a light-rose color it now shows a very intense red; furthermore, the granulations are prominent, very perceptibly projecting above the level of the wound.

Ten minutes after ten. Boot removed; the wound is not as red as before, and its surface is covered with a copious effusion of lymph.

Third Application (*April 30th*).—Fifteen minutes past nine. The wound is of a vivid red; granulations exuberant; cicatrization is setting in around the edges.

Thirty minutes past ten. We place the wound under the influence of oxygen. It is less red, even grayish at certain points. Serous pus covers its surface.

Fourth Application (*May 1st*).—Thirty minutes past nine. The granulations are more advanced than during the last few days.

Twenty minutes past five. The boot was not removed today until eight hours after the application of oxygen. At this time the wound shows a gray color; a kind of whitish crust covers the upper portion; granulations not very prominent, rather flattened, and of an indistinct red. The plastic exudation is quite copious, and, placed under the microscope, shows a considerable number of purulent globules.*

Fifth Application (*May 2d*).—Twenty minutes past nine. The color of the wound is a deep red; granulations well developed; a little suppuration of healthy appearance fills the furrows which separate the granulations; we can easily touch with the finger the external surface of the tibia, which is found to be denuded.

Thirty minutes past ten. An abundant liquid effusion covers the wound, which is of a pale red in places, and of a very bright red in others. Under the microscope we perceive large numbers of purulent globules suspended in serum.

May 3d and 4th. No applications of oxygen.

* This eight-hour application was certainly a mistake. If the prolonged effect of oxygen was desired, the boot should have been replenished with fresh gas constantly, or at least every hour.—TRANS.

May 5th. Granulations exuberant; the wound inflamed; raspberry-red, bleeding. Ordered poultices.*

It follows from this case, and from others which we have observed, that oxygen, on being kept in contact with a wound, causes the latter to assume a grayish tint, and excites a sero-purulent exudation; that it is only after the removal of the hood that a reaction takes place in the wound, which will prove salutary in case the wound is atonic, but which may exceed the limit of stimulation, and become in some instances actual inflammation, as the foregoing case clearly proves.

From all these investigations a certain fact is evident: it is that oxygen is a stimulant to wounds under whatever form it is applied to a living organism, whether injected into the veins, inhaled, or brought directly into contact with solutions of continuity; and that it is with just reason that Monro and Hunter have attributed to atmospheric air a stimulating influence in connection with wounds, a fact experimentally demonstrated by the labors of distinguished surgeons who have devoted themselves to the study of subcutaneous wounds. When M. Jules Guerin announced that oxygen is an excitant to wounds, he thereby advanced an unquestionable fact, of which, unfortunately, however, he gave no direct demonstration, as we have now done.

We have not only applied oxygen to the surface of wounds, we have injected it into the bladder, without its causing the slightest pain; at least, when this organ was not inflamed, and when the quantity injected was not large. In this latter case pain was caused, not by the agent itself, but by the distention of the urinary reservoir, which it produced. Injected into the bladder of a man who was suffering from retention of urine caused by enlargement of the prostate, it produced, in this case, neither malaise nor suffering. We have twice injected oxygen into the tunica vaginalis, without causing the least untoward symptom. In one case we effected a cure of hydrocele which had required relief by puncture. In another case the hydrocele returned, and it was necessary to follow with an injection of iodine. No accident and no pain worth mentioning followed either of these operations. The resulting symptoms were as simple as those in case of animals on which we practiced the

* The wound of this man, after omitting the use of oxygen, continued in fine condition, and rapidly progressed toward cure.

injection of air into the serous membranes. At the end of from five to twenty days the gas was absorbed.

One of the principal surgical operations to which we have devoted some thought, after having proved its harmlessness, has been the treatment of senile gangrene. Seeing that by the application of oxygen we in some degree antagonize congestion in a diseased organ, and that we encourage cutaneous exudation in case of a limb to which it is applied, we had hoped to stimulate the capillary circulation and to maintain it in the affected limb. But the results obtained, from the very start, have not been at all favorable to this theory. Our first attempts, which extended over several years, were made upon invalids who were suffering from senile gangrene and upon patients affected with [traumatic] gangrene, or, what is worse, with glycosuric carbuncles, terminating in gangrene. Not having succeeded with oxygen, we had recourse to carbonic acid with no greater success. But in the two following cases we succeeded in quieting the pains, once with oxygen, and once with carbonic acid. Here are the two cases *:—

Case XXII. John S., aged forty-five, a strong and vigorous man, in good health; never has been sick, except that he remembers some rheumatic pains, five years ago. About that time he developed an inguinal hernia of the right side, which is now painful and difficult to retain.

Says he has had, for a long time, a horny excrescence on the left little toe, situated near the junction of the first and second phalanges. October, 1862, violent pains set in; prevented sleep; extended to the whole foot. Tried various ointments, which merely produced a little redness at the point of application. This color was very marked on the outside of the little toe, soon becoming a vinous red, then purple, and finally blackish. The disease gradually extended to the entire toe and to the two adjoining toes.

MM. Louis Nelaton, the eminent surgeon, and Maisonneuve were successively consulted, and prescribed opiates, externally and internally. The evil steadily increasing, January 21, 1863, he was brought to the hospital. Three toes and the outer aspect of the foot became involved, and turned black. The plantar surface was equally involved, and all became as black as ebony,

* These cases, being given at length, are not deemed of sufficient interest to be repeated in full. They have, therefore, been considerably condensed.—Trans.

emitting the characteristic odor of senile gangrene. The circulation seemed entirely cut off in the tibial and popliteal arteries. No pulsation could be felt until the femoral, as high up as its upper third, was reached.

The thermometer indicated as follows: thigh, 35° C.; left foot, dorsal surface, 33°; right foot, external face of the dorsum, 33.8°. General condition of the patient, good.

Bathed the foot in the following:—

℞ Potass. permang.,	10 grams.	
Sydenham's laudanum,	10 "	
Glycerin,	30 "	—M.

January 23d. From twelve to one o'clock applied a continuous current of oxygen by means of a boot hermetically sealed to the limb above by a band of adhesive plaster, and by a rubber tube connecting the oxygen generator with the boot. Another tube permitted the escape of oxygen, which was conducted through a flask containing lime-water, where it could be seen that the gas, after having been in contact with the diseased part, was charged with more or less carbonic acid.

The pain subsided immediately after the introduction of oxygen, so that the patient slept for some minutes. A half hour after the application of the gas, pain reappeared with great violence and persisted for an hour; then subsided again, with occasional exacerbations.

The fœtor entirely disappeared. The sphacelated parts were somewhat harder, and the inflamed edges (which were faintly pink before) became redder.

From this time until March 14th, when the disease terminated fatally, we were able, by prolonging the application of the gas, to control the almost unendurable sufferings of the patient for several hours each day, enabling him to partake of nourishment and to procure some sleep.

It must not be forgotten that in this case there was obliteration of the popliteal artery and of the femoral, below its upper third, no pulsation whatever being perceptible in the arteries of the leg.

Another result of the application of oxygen was an improvement in the desiccation of the gangrenous parts.

In the following case we had recourse to carbonic acid in order to quiet the pains, a result obtained after prolonging the

application for several hours. Having accomplished this result, we then hastened the desiccation or mummification of the foot, by the aid of oxygen.

Case XXIII. *Senile Gangrene of the Left Foot Treated by Oxygen and Carbonic Acid.*—Mrs. A., eighty-four years of age, entered the hospital February 3, 1863. General health has always been good. The stethoscope detects no indications of valvular lesions of the heart.

Six weeks ago she complained of a sensation of numbness and cold, especially in the affected limb. About the 1st of January, sharp pain in walking was added to the feeling of numbness, and became so intolerable that she could not endure the upright position, and was obliged to keep her bed. The toes, she said, at that time appeared reddish, verging toward purple, especially the great toe.

At present the toes are bluish in color, at their bases. A large blister, filled with a yellowish sero-purulent liquid, covers the anterior portion of the dorsum of the foot.

Movements, or the lightest touch, excite the most excruciating pains, and cause the patient to cry out continually. No pulsation can be detected, either in the plantar, posterior tibial, or popliteal arteries. The femoral cannot be detected, except just below Poupart's ligament.

The characteristic odor of gangrene is present, and the comparative temperature of the two members as follows:—

Right foot (sound), 32.5° C.

Left foot (diseased), 34.4° C.

(Applied linen cloths saturated with glycerin. Ordered claret, cinchona, Spa water, and an opiate.)

February 5th. No change in the general condition. The diseased foot is not so red, and is less swollen about the blister, but the toes show a deeper color. Temperature,—right foot, 34°; left, 34.6° C.

February 7th. No change in the local condition. Pains less intense. Temperature (right), 34°; (left), 34.8.°

From the 7th to the 28th, the dorsum of the foot near the toes, and over all the surface originally covered by the blister, assumed a blackish tint. The toes darker in color, mummified, and gangrenous. Temperature, for several days in succession, 34.8° for the well side, 32.2° for the diseased foot.

March 1st. Fœtor increased. Pains as severe as at first.

Bed-sore from dorsal decubitus. Intellect affected; constant somnolency; anorexia.

Placed the diseased foot for two hours in a rubber boot filled with carbonic acid. This process, repeated for four days, relieved tne pains, but, as the fœtor rather increased, carbonic acid was replaced by oxygen. Three days of this treatment abated the fetid odor, and mummification of the toes and a part of the foot became complete. No further local change occurred, and a fatal termination followed on the 19th of March.

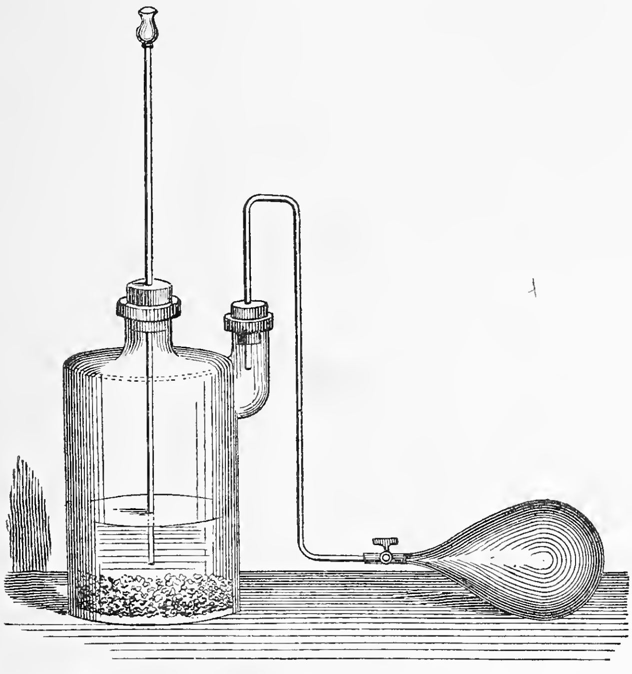


FIG. 8.—APPARATUS FOR GENERATING CARBONIC ACID.

No autopsy was permitted.

In another case, quite similar to the above, oxygen was applied locally from the latter part of August until October, two hours daily, and once or twice during the time oxygen was inhaled. But, beyond temporary relief to the sufferings of the patient, correction of the fetid odor, and more rapid desiccation of the parts, the results were not remarkable. This case, like the former ones, finally ended fatally. [It seems unaccountable

that inhalations were not more relied on as an adjunct in these extreme and hopeless cases.—TRANS.]

The cases which we have just reported are not particularly favorable to the external use of oxygen. We obtained, it is true, diminution of pains and more rapid mummification of mortified parts, but these results are insignificant in comparison with the object we had in view.

In another case, where M. Pellegrin had recourse to the same treatment, he was no more fortunate than we. We were therefore greatly surprised when M. Laugier reported to the Academy the two following cases selected from his practice. We must state, at this point, that the cases described by M. Laugier were entirely different from ours, since, in his two patients, arterial pulsation was preserved in the gangrenous limbs.

Gangrene doubtless depends more upon interruption of the capillary circulation than upon trouble with the large arteries; and in these cases, in which the larger arteries were not involved or interrupted, the progress of the disease was slow, but it was not less painful. . . . . Better informed to-day, through further experience, we are impelled to publish these two cases of M. Laugier; all the more, since in two similar cases we have derived from the application of this agent results truly remarkable, on account of the promptness with which they have responded to the influence. We will not attempt the interpretation of the facts given by the surgeon whom we are about to quote, but will limit ourselves to the publication of the cases:—

Case XXIV.* "The first patient to whom this treatment was applied was an old man of sixty-five years, who had suffered severe pain in the toes of the left foot for the space of two years. March 17, 1862, he entered the hospital. One toe was already black and insensible, with a dry slough fifty centimetres in diameter. The remaining toes had livid-red spots. Pain very severe. No cardiac complication. No appreciable changes in the course of the arteries. Pulsation distinct in the dorsalis pedis, the coats of which seemed to be healthy. Treatment: For two hours, daily, the foot was encased in a boot, through which a constant current of oxygen was kept passing.

"At the end of five or six days the pains were less intense, spots less in size, and taking on a rosy color. A few days later

* See the memoir presented in my name and that of M. Leconte; Comptes Rendus de l'Acad. Sci., 1862.

patient had no pains at all. Skin recovered its normal color, except at the edges of the sloughs. Sensibility restored.

"Early in April the appearance of an eliminated sulcus [line of demarkation?] indicated that the slough was about to be detached. April 10th the slough fell off, leaving a small superficial wound of healthy appearance. April 24th patient left the hospital, walking perfectly well. The oxygen baths had been continued up to the time he left."*

Case XXV. "The second patient was another old man, of sixty-six years, who, notwithstanding his age, followed the laborious occupation of a cartman. Six weeks before his admission the last two toes of the left foot became so painful as to compel him to stop work. He had noticed that the toes were at first livid, afterward blackish, and insensible to the touch. He was admitted to the Hôtel Dieu April 21st, and his case pronounced dry gangrene of the toes. The foot showed livid spots. No apparent lesions of the heart or blood-vessels.

"We at once placed him under the influence of oxygen baths [locally applied to the diseased member], and after a few days the pains ceased, and we could see the formation of a sulcus, which limited the disease, and indicated that nature was about to rid herself of the mummified part.

"An analysis of the mixture of gases issuing from the escape-tube attached to the boot showed a large proportion of carbonic acid, a little oxygen, and a very little nitrogen."†

We have here two cases from our personal experience which are not less interesting than the foregoing. We also had recourse to the application of oxygen by the aid of a very simple process. The member was placed in a large India-rubber boot, the upper end of which was closely applied, either above or below the knee, and hermetically closed by the aid of a bandage of adhesive plaster. We allowed the air contained in the boot or muff to escape, and caused to enter constantly a certain quantity of oxygen by the same tube which connected the interior of this apparatus with the external atmosphere. The limb was kept in this atmosphere (of oxygen) two or three hours daily, after which the boot was removed.

The most striking results of these applications of oxygen were:—

* Gaz. des Hôp. (l'Hôtel Dieu), 1862, p. 230.
† *Ibid.*, p. 274.

1st. Relief of pain. 2d. Stimulation of the capillary circulation. 3d. Decoloration of the parts, which rapidly lost their purple tint. 4th. Finally, detachment of sloughs, and cure.

Case XXVI. *Senile Gangrene. Recovery under Use of Oxygen.*—Mr. A., aged sixty-two, in June, 1850, had an attack of paralysis which resisted all forms of treatment in vogue. Moxas, blisters and cuppings gave slight, temporary relief. Was sent every summer to Luchon; but, while constantly expecting a cure, this result was as constantly delayed. Electricity, which in the hands of M. Duchenne has given such happy results, had frequently to be resorted to. Then dull pains began to be felt in both feet, a sense of coldness, of numbness, especially in the left foot, and on this account, during one season, he was prevented from going to Luchon. There were constant and persistent alternations of pain and numbness, which only frictions and electricity could ameliorate. In August, 1864, the left foot became the seat of the most lancinating pains; coldness and numbness pronounced; color purplish. Douches of sulphur-water gave no result, except a burning sensation and intolerable pains throughout the foot. A small ulcer appeared between the first and second toes. The use of opiates and emollients was followed by an ulcer on the fourth toe. Rest brought about a return of the general health.

On his return to Paris, the foot being angry, purplish and swollen, was rubbed with mercurial ointment; opium and belladonna were applied; the swelling subsided, but the two ulcers remained stationary and would not cicatrize. Called in consultation, we found an absence of pulse-beats in the pedal and anterior tibial arteries, pulsation being still present in the posterior tibial. The foot was livid; wounds presented an unhealthy appearance, with no tendency to heal; pains deep, piercing, and constant; patient suffering from insomnia. We prescribed oxygen, which was exhibited according to our suggestions.

After twelve days of the local application of oxygen the two ulcers, intractable under all former treatment, began at once to cicatrize, and the pains ceased. From that time Mr. A. resumed his business, he could walk with ease, and was even able to follow the chase.

Case XXVII. *Spontaneous Gangrene of the Third Toe of the Left Foot. Local Oxygen Baths. Recovery.*—Mrs. L., aged fifty-six, entered the City Hospital, April 18, 1865; mother of

two children, has a good constitution, and has always enjoyed good health. Notable dilatation of the innominate artery is easily perceptible at the level of the sternal bifurcation. Eight days before her admission, pains began in the toes of the left foot; severe at night. A few days later the third toe showed purple discoloration, verging toward black, in places. A small ulcerative patch appeared on the third toe. The arteries of the foot still pulsate. The temperature of the diseased foot is less than one degree above that of the healthy one. April 21st, applied a rubber boot, enveloping the limb to the knee, and filled it with oxygen. It was left in position seven or eight hours, after which opiate poultices were applied.

This treatment being continued, the patient soon announced that the nocturnal pains had sensibly diminished.

April 27th. A scab or slough becomes detached from the ulcerated toe and falls off, leaving a raw but bright-red excavation of some depth. The purple color of the diseased toe gradually disappears; cicatrization follows, pains entirely ceasing.

May 20th. Oxygen baths discontinued, and the foot bathed with glycerin. A few days later the patient left her bed and walked. The foot had healed.

(*b*) Inhalations of Oxygen in the Treatment of Surgical Diseases.—In view of the facts set forth in the preceding chapter, we have deemed it desirable to employ oxygen to revive patients exhausted by suffering or prolonged suppuration. In these cases anæmia and dyspepsia are often very difficult to overcome; and if we have occasion to operate on these unfortuntae patients, under these conditions, we run a great risk of losing them. How often, after performing operations, even of moderate gravity, we have been mortified at losing our unfortunate subjects, from want of means at hand to resuscitate them, to give a fresh impetus to the nervous system, and to revive in them a sense of the necessity for restorative efforts in their own behalf. In fact, suppose that an unfortunate subject, who has already suffered much, is anæmic, without appetite, taking nourishment without relish, is subjected to a severe operation, an amputation, a resection, or the removal of a tumor. This done, strive to nourish him, to restore his strength, so long reduced, and to reproduce, if possible, a volume of blood sufficient for the accomplishment of all the functions of life. We insist, with reason, on better alimentation, on the use of better wine; but the

digestive forces have been weakened, the blood itself is essentially changed, both in quality and quantity, and is no longer capable of adequately vivifying the organism. His wounds languish, suppuration becomes unhealthy in character, and this without a sufficient local disease to account for this condition. The patient is going to succumb for want of vitality. Now, if in this emergency we cause the patient to inhale, morning and evening, fifteen to twenty litres of oxygen, pure, or mixed with an equal quantity of common air, we will often succeed in reviving his strength, depressed by the operation, will arouse his appetite, and very soon we shall see one whom we had believed was doomed to certain death beginning to convalesce. Since we introduced oxygen into our service we have many times had the pleasure and satisfaction of thus restoring prostrated patients.

Case XXVIII. One of the cases which most impressed us was that of an unfortunate young man who was sent to us from the country, and on whom at the time of his admission we had performed amputation of the leg at the lower third, on account of a white swelling, involving the tibio-tarsal joint. This poor fellow, about twenty-five or thirty years of age, had reached the last degree of debility. We had hoped that, once relieved of the source of infection and exhaustion which he had dragged about with him, he would recover his appetite and strength. Unfortunately, he did nothing of the kind. He continued to decline, and notwithstanding our urgings he took very little nourishment. He felt a thorough distaste for every form of food. At this juncture we placed him on the use of oxygen. In a few days his appetite returned, and we could see that he was recovering from the profound anæmia and extreme emaciation into which he had fallen. This case, which was the first one in which we had used oxygen with a view to restore the patient after an operation, has impressed us forcibly. Our patient promptly recovered, and, with the aid of a prosthetic apparatus, walked very well. Some time afterward we reported to M. Trousseau the facts of a not less interesting case :—

Case XXIX. It was that of a young Spaniard, exhausted by severe hæmorrhages and profuse suppuration. He refused every form of nourishment, anorexia being absolute. Under the influence of oxygen he recovered, promptly, both appetite and strength, and his life, so nearly spent, was prolonged in comparative comfort for two months.

These two cases have decidedly encouraged us to persevere in the inhalations of oxygen.

Here is another case, more in detail, in corroboration of the good results which may be obtained. This time the individual was so exhausted that we thought it necessary to continue the inhalations of oxygen, even during a course of lymphangitis, which occurred during his convalescence.

Case XXX. *White Swelling of the Tibio-Tarsal Joint. Amputation of the Leg at the Lower Fourth; Extreme Debility and Anæmia. Inhalations of Oxygen Gas.**—On the 20th of October, 1863, a married man of forty entered the City Hospital. He was employed by the Council of State. Nervous temperament and shattered constitution; for many years a valetudinarian. He has a sallow complexion and is emaciated. Has coughed for four or five years, and rarely passes a winter without having bronchitis; voice frequently hoarse.

A year ago, by the advice of a Parisian physician, he spent a season at Amelie-les-Bains, for the purpose of having his joint affection treated. We carefully auscultated the chest of this patient without being able to detect the least symptom of tubercular phthisis. The right tibio-tarsal joint was very much swollen, and there was considerable œdema of adjacent parts, extending to the malleoli. Movement of the joint caused sharp pain, and crackling sounds could be heard, indicating that the cartilages were being destroyed. The foot was kept immobile, and with forced extension; it was uniformly œdematous; pressure was painful. There were numerous openings in the vicinity of the joint, which gave exit to a considerable quantity of thick, fetid pus, or rather of a fluid, sero-purulent in character, resembling the discharge coming from an abscess produced by congestion. For a year, has had to give up his occupation, keep his room, and, as he says, most of the time, his bed.

At first his trouble was not understood. It was not considered grave, even in view of the constitution of the patient, which was manifestly scrofulous.

M. Demarquay, after having carefully examined the patient as to his general condition and exploring the wound with a probe, discovered that there was caries of the tibio-tarsal joint and of certain of the metatarsal bones, and decided to practice amputation.

* Report rendered by M. de Lavaysse, externe of the hospital.

This operation was effected at the point decided upon, namely, at the lower fourth of the leg, on the 26th of October.

But we now come to the inhalations of oxygen, which we prescribed on the 3d of November, at the rate of fifteen litres every morning, then twenty and twenty-five litres.

At first the gas was mixed with one-fourth air; after a few days the proportion of oxygen was increased, and, finally, the gas was administered pure.

The following are the phenomena observed in connection with this patient:—

At the end of the first inhalation, which lasted three minutes, the pulse, which was 72 before, rose to 80; the skin about the chest became moist, and the hands decidedly so.

No effects were produced on the organs of sense; no disturbances of the vision; no roaring in the ears.

No cerebral symptoms, neither vertigo nor obtuseness; no ephemeral delirium noticed; no tingling at the ends of the fingers.

The patient, who has suffered from anorexia for a long time, and whose nights have been almost without sleep, at the end of a few days showed marked evidences of improvement.

We call especial attention to this phenomenon, which has been a frequent occurrence with a large majority of our patients,—the prompt restoration of appetite.

In fact, after a few inhalations, the invalid eats more, and with much more relish; more frequently feeling the need of filling his stomach.

This patient's nights became better; said he breathed more easily. From being emphysematous and extremely short of breath, he felt that his chest expanded more easily; and for some hours after inhaling the gas he experienced a sense of well-being and of active life.

November 10th, the patient had a violent chill, followed in an hour by intense heat, and finally by a profuse perspiration. Before and after the fever he felt a general malaise, anorexia, insomnia, intense thirst. (Infus. tiliæ; quinine.)

The wound became more painful; next day it was dryer and redder in color. (Glycerin dressing.)

The 11th and 12th of November the glands of the right groin became congested, and some erysipelatous spots appeared at the margin of the stump. Red streaks were seen running

from the wound toward the inguinal region. Lymphatic vessels inflamed. This angioleucitis and the fever persisted for fifteen days, and we were permitted to observe a very curious fact, thus: in spite of the angioleucitis and the fever, the patient successfully resisted this serious complication, aided by the inhalations of twenty litres, and then of twenty-five litres of oxygen, diluted one-fourth with air.

This invigorating inhalation, notwithstanding the copious sweats and a pronounced febrile condition, enabled the patient to more energetically combat that depression and prostration which always accompanies traumatic erysipelas.

The wound assumed a healthy aspect; and where we had employed twenty-five litres of pure oxygen, as we did upon the decline of the angioleucitis, after its third recurrence, we beheld the amputation wound become very florid, the granulations turgescent and of a rosy red, and the whole surface suffused by a copious exudation of plastic lymph.

December 5th we stopped the use of the gas, which in case of this patient had promptly improved the general condition. The strength, appetite, general appearance, and the facies were all quite changed. During the first fortnight of December the patient left his bed and walked a little, with the aid of a crutch. He had also gained a little flesh, and the wound was almost entirely cicatrized.

It is not rare to see profuse hæmorrhages follow operations, even of slight nature, in individuals exhausted or debilitated, on account of serious changes taking place in the blood, or from other circumstances. In these cases we administer iron, and endeavor to revive and strengthen the patient's appetite, but often the repugnance for food is unconquerable. It is then that oxygen renders great service. It re-invigorates the central nervous system, and arouses in the exhausted individual a desire for substantial nourishment. We have many times seen, both after operations and in patients extremely prostrated by metrorrhagias, following, for example, uterine polypi, a virtual return to new life.

Case XXXI. *Case of Tubercular Epididymitis, with Probable Inflammation of Cowper's Glands; Anal Abscess; Severe Hæmorrhage. Respiration of Oxygen. Recovery.*—H., aged nineteen years, a tradesman, entered the hospital October 29th.

Five or six months since this patient came for the first time to the hospital (service of M. Cazalis) on account of pains experienced in the left inguinal region. After a few days M. Cazalis sent him to the country and prescribed for him a milk diet. Notwithstanding this his condition was not improved. Soon the abdominal pains, which had subsided for a few days, returned, and with them swelling of the inguinal glands, and a similar tumefaction of the left testicle. Rest for three weeks was followed by some improvement. He returned to his warehouse in Paris.

October 29th he returned to the hospital and came under the care of M. Demarquay. Complains of constant pains in the perineal region; the sitting posture being almost impossible, he is obliged to stand, and when fatigued he lies down flat on his stomach. There is still a small tumor in the left testicle.

Examining the perineal region we find at the base of the ischio-urethral triangle a tumor about the size of a large nut. Elliptic in form, its longest diameter is parallel with the median raphe, which divides it into two unequal parts, the left side being the larger. The skin over it is sound and does not adhere to it at any point. It is very painful, even to the slightest touch.

M. Demarquay diagnoses inflammation of Cowper's glands. The left epididymis is swollen and contains three small indurated tumors. From the external characteristics of the affection of the testicles and the history of the case, we believe the patient to be suffering from the tubercular diathesis, and yet exploration of the chest discloses only a little harshness in the respiratory murmur.

November 6th. The tumor has diminished in size, and is not so painful to the touch. Nevertheless, on palpation, we detect indistinct fluctuation.

November 11th. The tumor is incised, and discharges a large quantity of pus.

On the following days it discharged a serous and fetid pus; an extensive detachment of the skin followed; the fibres of the ischio-cavernosus were uncovered, but there was no communication with the urethral canal. General condition quite satisfactory.

November 28th. A profuse hæmorrhage occurs. The next day, at the time of the visit, the patient was on the verge of collapse; countenance pale, eyes dull; extreme prostration. Demulcent drinks, wine, beef-tea, and soups.

November 30th. M. Demarquay suggested that the patient should inhale oxygen for a few days.

Two days after commencing the oxygen, patient was less depressed and his color improved. He could eat a little. Nevertheless, the wound still discharged a grayish and fetid serum.

At the end of eight days we observe a marked change in the appearance of the wound and in the general condition. The wound has changed to a rosy red; he has color in his face, and he assures us that his appetite has decidedly improved since he began to respire oxygen. Second-grade diet.

December 15th. The patient is found in a very satisfactory condition. The wound has assumed a vermilion hue. We place him on fourth-grade regimen.

December 29th. The improvement has continued. We shall only wait until the wound has completely cicatrized before dismissing him.

It is evident to every one that an operation is just as much more serious as the individual is more reduced and debilitated. The pain and loss of blood inseparable from every operation adds to the gravity of the case. Of course, we always hope that the individual, when relieved of the source of his debilitated condition, will take on new life; but, alas! how often we are deceived in our hopes. Thus, when we have found ourselves confronted by similarly afflicted patients, unless there have been decided contra-indications, we have advised inhalations of oxygen in doses of ten to thirty litres *per diem*, taken at two different times, mingled with a certain proportion of air, morning and evening, a little before eating; and it has often been our experience to see, so to speak, regenerated individuals, their digestive powers revived, and these same patients enabled to undergo a severe operation, which, without having been previously fortified, they could not have survived.

Case XXXII. *Tubercular Fungoid of the Testicle; Very Feeble Constitution; Dyspnœa and Anæmia. Respiration of Oxygen. Cure.*—Mr. A., aged thirty-five, architect, entered the City Hospital (service of M. Demarquay) on July 27, 1865, for the purpose of being operated on for tubercular fungus of the left testicle. This tumor was ulcerated, and ulceration was daily spreading with great rapidity. The patient demands the operation, which the disease he is suffering from evidently requires, but which is contra-indicated by his general condition. For

months, in fact, he has been greatly reduced. He has profuse and very frequent sweats. The mucous membranes are pale, appetite capricious, and digestion difficult. Moreover, the patient had previously had an attack of articular rheumatism, which left him stiff in several joints. Under these circumstances an operation is not to be thought of. The surgeon, perchance, manipulating in the region of a hollow viscus might produce a hæmorrhage, and even if this should not be very profuse it might prove very dangerous for a debilitated patient. It is necessary then, first of all, to arouse and restore his appetite. Hence, at the same time that we placed this patient on tonics we caused him to inhale, daily, ten litres of oxygen, increasing the dose a few days later to twenty litres. Two days after this the patient acknowledged an increase of appetite, which soon became very keen. He rapidly improved in appearance; the mucous membranes showed color, and his strength increased so much that on the 21st of August we were able to operate for the removal of the testicle. In the afternoon a hæmorrhage occurred, which it was necessary to check with a salt of iron.

Notwithstanding this, the cicatrization of the wound progressed very nicely, the general condition improved, and to-day, October 10th, the wound is closed; the patient presents an excellent appearance; he walks,—in a word, his present condition is in striking and happy contrast to that which he presented on his admission.

This case has impressed us very forcibly. Certainly, without the aid of the oxygen inhalations the patient would not have been able to endure the operation of castration, and would not have rallied from a somewhat severe hæmorrhage.

We have frequently had recourse to carbonic acid and to oxygen, locally applied, to combat rebellious ulcers and wounds of an unhealthy character. Furthermore, after Beddoes and his pupils, we have had recourse to inhalations of oxygen in case of old wounds of an unpromising nature, even those of specific character and origin, and always with the greatest advantage; not that in these cases oxygen has any specific property; its action is, rather, entirely natural and general. It acts especially by restoring and reviving the energies of the system, so that the wounds, as a result, get well of their own accord.

We find also in Beddoes:*—

* Beddoes, Consid. on Factitious Airs, part i, p. 65.

Case XXXIII.—1. A case of scrofulous ulcers of the arms and of the leg, cured after a few weeks by inhalations of vital air.

Case XXXIV.—2. A case of ulcer of the leg, of eighteen years' standing, treated in vain for four years by Pott, and for twenty-seven months by Sharp, cured at the end of four weeks under the influence of oxygen inhalations; no relapse having occurred six months later.*

Case XXXV.—3. A case of old scrofulous ulcer of very bad aspect involving one of the arms of a debilitated subject, in which daily inhalations of oxygen in increasing doses, diluted with atmospheric air, at the end of a month resulted in a degree of betterment of the general condition that was fairly astonishing, but without inducing a tendency to cicatrization in the ulcer. On the contrary, after a time, there was irritation and inflammation of the ulcer. Then the stimulation produced by oxygen was modified by adding to this gas a certain quantity of carbonic acid. In less than a week the inflammation had disappeared, and the ulcer showed a tendency to cicatrization. The dose of mixed gases was increased and the patient recovered.

Case XXXVI.—4. Finally, a case of very extensive ulcer of the leg (four inches long by three inches wide), so deep as to have involved the muscular tissues, of an uncertain origin, but of very bad appearance, and occurring in a subject extremely debilitated. "For a year there had been used a multitude of topical applications, and the administration of tonics internally, but without other change than the constant advance of the malady. The patient, Mr. Atwood, although not bedridden, was in a very bad general condition; ordinarily no appetite; constant nausea; wound atonic, painful at times, and much of the time accompanied by insomnia.

"From this time Mr. Atwood was placed upon oxygen, diluted with a little air, and a rapid change was inaugurated. His appetite was restored, and this was the first effect produced by the gas; sleep became more feasible, more restoring, and his strength returned. Moreover, the general condition was very perceptibly ameliorated."

It is to be noted that this patient, whose history Beddoes took care to hand down to us in his work, the "Journal," describes exactly, day by day, the very same sensations that have occurred to our patients.

* *Op. cit.*, part i, page 66.

Meanwhile, the local condition was changed. The ulcer took on a better aspect; it discharged a laudable pus, and at the end of five days it was three-fourths healed over. Six weeks from the commencement of the treatment cicatrization was complete.

In these cases, and in others which have occurred in our personal experience, oxygen has never failed to act as a thorough modifier of the system, which, restored to a better condition, cures itself. Encouraged by these cases and by our own experience, we would ask, with regard to a case which will be reported further on, whether we could not administer oxygen with advantage to subjects suffering from phagedenic and serpiginous chancres. It is very evident that with these subjects the important point is to change their constitutional condition; hence, outdoor air and good nourishment often accomplish more than all our medications. Now, what do we accomplish with the oxygen? We develop the appetite of the individual; we profoundly modify nutrition by favoring assimilation; we perceptibly change the condition of the blood. It is, then, not at all astonishing that we should cause the cicatrization of rebellious, and even of phagedenic and serpiginous ulcers. The following case proves this. We publish it without comment, just as it was reported:—

Case XXXVII. *Phagedenic, Serpiginous Chancre (in an extremely debilitated subject) of Eighteen Months' Standing, Invading the Perineum, the Pubes, and the Thighs to a Large Extent. Inhalations of Oxygen. Cure.**—October 15, 1863, a young Englishman, native of London, aged twenty-five, entered the City Hospital, having arrived in Paris the same day. An interpreter assisted me in taking the following statement:—

Has had several attacks of gonorrhœa since the age of twenty; has had orchitis of the right side. The last gonorrhœa dates back several months previous to the invasion of a chancre, which now presents a phagedenic character at several points.

The chancre originated eighteen months since. It was at first located at the meatus, but was cured in a month, and has left no discernible cicatrix. The patient was attended at first by M. Johnson, surgeon to St. George's Hospital, London.

The chancre, the patient asserts, was completely cicatrized under the influence of local bathing and constitutional treat-

* Case reported by M. de Lavaysse, externe on duty.

ment by corrosive sublimate. About fifteen days afterward a point in the groin ulcerated. After being simply dressed for a few days, this ulcer, perfectly round in form, daily grew larger and soon became as large as a five-franc piece. It cicatrized at the centre and constantly spread at the edges.

During the four months that the patient remained in St. George's Hospital, both groins, the inguino-crural folds and the perineum were successively invaded. The patient suffered severely when the wounds were exposed to the air during the time of dressing; and when they were being bathed with the various lotions, which it is not necessary to mention, it grew angry and bled.

The patient was condemned to the most absolute immobility. He could not flex the thighs in the slightest manner, nor bring them into a condition of abduction without causing them to bleed, without tearing the chancrous surfaces, nor without increasing his sufferings. He became greatly debilitated, rested badly at night, lost his appetite, and daily became more and more emaciated. From time to time he was taken with diarrhœa.

They prescribed, internally, mercurial treatment. As a dressing, powdered charcoal and cinchona. Diet, the hospital "tonic," *i.e.*, Bordeaux wine and mutton chops.

At the end of these four months the patient went home for nearly five months and followed a different treatment. Afterward he entered the venereal ward of St. Bartholomew Hospital, where he remained four months. No improvement.

The patient again left the hospital and remained several months at his father's. Upon the advice of some parties he decided to come to France and try the treatment of this hospital.

This urethral chancre which has made such ravages, which, sparing the testicles and the penis, has encroached upon the groins, the pubis, and the entire perineum, and the inner and upper parts of the thighs, had then had ten days of incubation. The woman who infected the patient, at Manchester, had been treated for syphilis in a hospital at Liverpool.

The condition of this patient at the date of his admission to the *Maison de Santè* was as follows:—

The whole extent of the perineum and all around the anus was almost entirely covered with white cicatricial tissue, wrinkled, hard, having contracted and drawn toward itself the

surrounding skin. At the anterior portion of the perineum we found two circles, somewhat larger than a silver five-franc piece. The surface mostly red, but gray at some points; edges raised, fringe-like, and partly detached. The urethra bled at the slightest touch with a sponge intended to cleanse the sore. At the completely shaved pubis we found four large circles or patches similar to those in the perineum. They were covered with a thick brown scab, which was easily broken and detached with the finger-nail. Underneath we found a slightly-depressed ulcer, varying in color from one point to another, in places gray, in others deep red, while at still other points the surface was flecked with a dirty red, sanious fluid.

On the inner and upper parts of the thighs we found two circular patches, larger than a franc piece, not covered by a scab. These chancroid ulcers, always invading the contiguous parts in the form of a circle, were cicatrized in some places and furrowed in others. They extended superficially rather than in depth.

During the four months spent in St. George's Hospital the left inguinal glands suppurated.

On the 16th of October, M. Demarquay removed the crusts, formed by the dried pus which covered these circular patches, and bathed the surface of the chancres with aromatic wine. We continued this dressing and the prescribed treatment.

Bands of compound mercurial ointment were applied, and covered with a thick layer of carded cotton. The whole was held in place by a few turns of a bandage.

As a treatment and *régime*, wine of cinchona, mucilaginous (gum) tea, roast meat, Bordeaux wine. The dressing was re-applied at the end of five days, and this course was continued for nine weeks (sixty-five days). From the 23d of October we caused the patient to respire each morning twenty litres of a gaseous mixture in the following proportions: air one part, oxygen three parts, *i.e.*, fifteen litres of pure oxygen.

The following are the principal phenomena observed:—

The pulse increased from seventy-six to eighty, and sometimes to eighty-four pulsations. This phenomenon is quite variable, as we have observed with several patients.

The skin became slightly moist. The countenance, previously pale and wan, took a little color, especially the lips. Was this due to the action of oxygen on the system, or to the efforts of the patient to breathe properly by the aid of the apparatus used?

No headache. No impediment [sense of weight?] between the root of the nose and the frontal sinuses. No constriction at the temples.

We did not observe in this patient, concerning the physiological phenomena connected with the senses, any disturbance of vision or of hearing. No prickling in the fingers.

We used, for some eight days, as much as twenty to twenty-five litres of pure oxygen per day.

We urged upon the patient to breathe slowly; that is, to retain the gas for a long time in the lungs, and to make the inspirations deep and full.* In this way the gas, remaining for some time in contact with the dark blood, may be more readily assimilated, and hence will effect more rapid hæmatosis.

The pulse was accelerated from four to twelve beats. The skin became moist. The patient experienced an unaccountable sense of well-being, of physical comfort, and, in a word, felt happier.

These sensations disappeared after a time. There were no flashes before the eyes, no ringing in the ears, no momentary intoxication. Through the temples and in the frontal sinuses the patient felt a kind of uneasiness or embarrassment, which persisted for fully half an hour. From the 13th to the 19th of November we administered to the patient thirty litres per day of the gas, mixed with air in the proportions already given.

We observed the same phenomena as before, but we ought to state that the patient did not uniformly exhibit all these symptoms. Several times a sense of warmth, chiefly under the sternum, or in the walls of the chest, together with some moisture of the hands and over the thorax, were the only symptoms observed. Acceleration of the pulsations and diminution of the fulness of the pulse did not follow.

Ephemeral intoxication, a kind of gayety, of cerebral exaltation, such as is produced by a small quantity of alcohol or of rich wine, was not produced as often as with women or with young subjects; but under the influence of a larger dose of pure oxygen, from fifteen to forty litres, a feeling of well-being, the flashings, and vertigo were distinctly perceived.

To conclude this report, we will speak of the results of

* This is an essential point, and very many cases treated with oxygen fail of any decided results on account of carelessness or negligence in this respect. Too much stress cannot be laid on this suggestion.—TRANS.

the treatment on the general condition of the patient and on the chancroid patches. During the first few days there was no effect as regards the phagedenic ulcers. Inhalation of pure oxygen merely reddened the wounds. They began to be covered with a profuse sero-purulent effusion. The bottom of the ulcers became of a bright-red color.

One month after commencing this treatment the larger portion of the chancroid patches were covered with a thin pellicle of cicatricial tissue. At certain points the patches had completely cicatrized. At other points the chancre, still red, invaded the contiguous parts.

We several times cauterized these points with acid nitrate of mercury, or with a pencil of nitrate of silver. Then we washed the wounds with aromatic wine, and covered the whole with strips of compound mercury-plaster, a thick layer of cotton, and a double bandage.

December 4th. The inhalations of oxygen ceased to-day. The general condition of the patient is much improved. His strength has returned, his complexion shows a tinge of color, and he has gained a little flesh. He has a voracious appetite, and the hospital fare does not satisfy him (being English, he is naturally a great flesh-eater).

December 28th. Cicatrization is almost complete at all points. In two places, only, little ulcers remain, smaller in size than a silver franc piece.

These were cauterized and dressed as before, and in a few days the patient was completely cured.

Here we have a young man exhausted by a chronic venereal disease, which had been treated for a long time. He enters the hospital reduced in health, and at the end of two months and a few days he is cured. He has regained his strength and his flesh, thanks to oxygen, which was the only remedy employed.

Case XXXVIII. While this patient was under treatment, a lymphatic young man, eighteen years of age, came under our care, to be treated for two immense buboes, following soft chancres. This very intelligent young man, a grocer's clerk, exhausted by fatigue, night-work, and insufficient nourishment, saw the wounds resulting from these buboes become true phagedenic ulcers, invading both groins. We applied the following treatment: He was dressed with charpie, saturated with glycerin, and was placed on the use of oxygen in large doses, twenty litres

morning and evening. Under the influence of these inhalations he acquired a ravenous appetite, eating and digesting food enough for two men. At the expiration of a few days the spread of the ulcers was arrested; they ended by becoming clean, and, finally, this young man was cured. One incident in this case forcibly impressed us. It was, that, although this young man consumed a large quantity of food, he apparently grew thin before our eyes, from the effects of very large doses of oxygen. Thus, we were compelled to substitute smaller doses, and he was completely cured.*

This year, again, we had an opportunity to use oxygen in a similar case. In this case we were obliged to arrest numerous hæmorrhages, which compromised the life of the subject, by cauterization with the actual cautery. In this case, too, the action of oxygen was not in the least uncertain.

Case XXXIX. *Phagedenic and Gangrenous Chancre of the Penis; Severe Hæmorrhage. Administration of Oxygen.*† [This case, covering conditions similar to those of the foregoing one, is much condensed from the original.—TRANS.]—Emmanuel C., twenty-seven years of age, warehouse clerk, entered the hospital January 3, 1865, suffering from gangrene of the penis. The primary sore first appeared toward the end of November, 1864. He denuded it, and a little pus escaped. From this it enlarged and became an indurated chancre. He paid little attention to it; made at the time some forced marches, and drank excessively. By the last of December the "button," as he called it, had acquired very uncomfortable proportions. It had enlarged, and suppurated profusely and regularly. Penis greatly swollen, with paraphymosis. The glans began to grow black. A serious hæmorrhage occurred under the swollen prepuce, at the edge of the chancre, and the patient entered the hospital January 3d. Charpie, saturated with perchloride of iron, arrested the hæmorrhage.

The patient was lymphatic, and presented the facies of an anæmic man. No appetite; genital organs swollen and œdematous; the glans black and gangrenous; copious discharge of

* Here, as in other instances, the author's conclusions have not been corroborated by my experience. In one case in my practice, a lady suffering from syphilitic eruptions surreptitiously crowded her treatment to the extent of inhaling thirty to forty gallons (one hundred and twelve to one hundred and fifty litres) per day, the only untoward result being a feeling of muscular lassitude and some unusual fatigue.—TRANS.

† Case recorded by M. Barlemont.

pus from beneath the prepuce; corpus cavernosum partly destroyed; glans attached to the body of the penis only by the urethra and the integument posterior to the canal.

January 5th, M. Demarquay proceeded to reduce the paraphymosis by an incision of the integument of the dorsal surface. A small ligature was necessary.

January 7th, the glans separated from the body of the penis without accident.

Dressing of perchloride to combat the tendency to hæmorrhage from the denuded stump.

On the 8th his sufferings, which up to this time had been very severe, became rather more endurable. Wound grayish and emitting much fœtor. The general condition slightly better.

On the 9th swelling began to subside. Fever slightly abated.

January 10th–11th, severe hæmorrhage from the corpus cavernosum, which persisted in spite of applications of pure perchloride of iron. Compression and applications of ice control it for a time; but it recurred in the morning, and M. Demarquay decided to arrest it with the actual cautery [*fer rouge*]. Corpus exposed by an incision, and several deep cauterizations succeeded in arresting the hæmorrhage.

January 12th. Patient passed a good night. Wound begins to suppurate (glycerin dressings). Patient much weakened by the loss of blood; pulse 90, thready, feeble.

On this and the two following days, caused the patient to inhale twenty litres of oxygen each morning.

January 15th. Appetite returning. Unavoidable neglect of oxygen for several days—the pharmacist failing to supply the gas.

Appetite continues; wound changed from its rosy red to a grayish color, its color and odor indicating a phagedenic condition.

January 23d. Oxygen again administered. The rosy tint of the wound returns and the swelling diminishes. Appetite soon becomes ravenous. General condition evidently improving; pulse recovers its fulness, and the countenance, from being pale and exsanguinated, assumes a healthy color.

February 3d. Oxygen omitted; appetite remains eager. Wound presents a good appearance, the artificial meatus assuming its proper position as the swelling subsides.

After Beddoes, we have given oxygen to cure scrofulous

ulcers. We have still under our care a patient with two scrofulous ulcers of the groin, and, in conjunction, two very large abscesses of a similar nature. Six weeks of ordinary treatment had not changed the condition of the parts. After a few days' inhalation of oxygen the ulcers changed their appearance; appetite and strength returning. Nevertheless, these cases are, to us, not at all astonishing. They are but the results of the physiologic action of oxygen.

Knowing the properties of this gas, it was entirely natural to apply it in the treatment of diseases of the bones and joints. Dr. Thornton, in a letter to Beddoes,* cites a case of white swelling treated and cured by oxygen. We have not been as fortunate as this disciple of Beddoes. In a case of even chronic arthritis of the knee, after having decidedly improved the general condition, we have seen the joint pains aggravated. We believe, in fact, that in a pathologic and therapeutic point of view it is necessary to discriminate between different cases of chronic arthritis. One variety may have a rheumatic or gouty origin; another is the result of a traumatic lesion; and others still are but a manifestation of scrofula. Perhaps the latter are the only cases in which we can use oxygen with positive assurance. Our experience has not been sufficiently extensive for us to decide. But we know that if we restore in a patient appetite and power to assimilate food we can profoundly modify a diseased organism and put it into infinitely more favorable conditions for recovery. It is necessary also to ask, the organic strength being thus restored, whether the individual will not better assimilate the modifying agents which may be administered to him. In fact, it is not sufficient merely to give nourishment to a patient in order to make him live. It is necessary that he should digest and assimilate it, and that he shall oxidize and eliminate those elements which do not go to make up part of the organism. Very well, it is the same with a drug. In order that it may act upon the blood and the nervous system it is necessary that it should be absorbed, and in order that it may modify the entire economy it must be subjected to a special assimilation. In order to attain this end it is necessary that this work be accomplished, and it is this that oxygen marvelously favors by arousing and strengthening the forces of the organism. Note a curious case, which we borrow from Hill, and in

* *Op. cit.*, part iii, p. 85.

which figure the names of two of the great surgeons of that age:—

Case XL. *White Swelling of the Knee.**—"Richard George, thirty years old, was attacked, in May, 1787, with rheumatic fever, but soon recovered. Toward the end of the following month he had a severe remittent fever. Dr. Warren was called and cared for him for three months, during which the patient suffered violent and general pains. Both knees became highly inflamed, painful, and swollen, especially the right, which had some months previously received a severe contusion.

"After having been greatly debilitated by the pain, fever, and prolonged confinement to bed, Mr. G., on the advice of Dr. Warren, went to Buxton. The waters of Buxton relieved the stiffness of the joints, and by the end of October the latter had recovered a certain degree of strength. The right knee, however, remained somewhat weak. On the slightest fatigue, as from a walk or hunting party, it always became painful, swollen, and it required some days of absolute rest to bring relief.

"Similar renewed attacks ended by injuring the articulation, and soon fluctuation could be detected about the joint.

"In 1789 Dr. John Hunter was consulted. He prescribed laxatives and sea-bathing, but this was followed by neither improvement nor aggravation.

"Up to 1794 the disease had grown no worse. At this period Mr. Cruikshank, called in consultation, punctured the capsular ligament with a lancet, and gave exit to a small quantity of yellow, glairy fluid. The opening quickly healed, leaving the knee neither better nor worse.

"In June, 1795, he was freshly attacked. There was high fever, with severe pain and tumefaction. These symptoms continued for several weeks, during which the region of the joint became greatly enlarged.

"The constitution of the patient now seemed greatly impaired. Another surgeon was called, and, after having noted the thickening of the tissues and the infiltration and alteration of the osseous surfaces, he gave a very grave prognosis. After several methods of treatment had been tried in vain, two blisters were applied, then two cauterizations, which were repeated at intervals for a year, up to October, 1796.

"At this point, on the recommendation of Dr. Beddoes, I

* Hill, Pract. Obs., etc., p. 42.

was consulted. The surgeon said to a friend of the patient that in a short time nothing but amputation would avail.

"Mr. G. having been confided to me, I placed him on the use of oxygen, and at the end of a few weeks the improvement was such that a cure could be reasonably hoped for. He had been scarcely able to climb the stairs, even with the aid of crutches, but at the end of six weeks could walk a mile, with the help of a cane, without producing fatigue, stiffness of the joint, or pain, although transient pains still occurred from time to time. This improvement continued, and six months afterward the constitution of the patient was quite fully restored, and the knee was so nearly well that he could walk three or four leagues without inconvenience.

"This gentleman continued perfectly well during a subsequent observation of more than three years."

Case XLI. *Case of Osteitis of the Fifth Metatarsus; Anæmia. Employment of Oxygen.*—Amelia B., aged twenty-eight, entered the City Hospital, June 3d, service of M. Demarquay.

Temperament, lymphatic; is anæmic, with decided paleness of the mucous membranes, cardiac murmurs (anæmic), and especially complaining of a total loss of appetite and intense disgust for food.

She presented, on the outer surface of the right foot, a purplish ulceration of an alarming appearance. On introducing a probe the fifth metatarsal bone could be readily felt, and was partly denuded. An unhealthy suppuration was going on in the wound. Having been freely laid open and several times injected with tincture of iodine, the character and appearance of the wound changed. To combat the anæmia and the loathing for food, M. Demarquay placed the patient upon inhalations of oxygen. Twenty litres per day were given, and at the end of the third day (June 17th) the patient experienced a sensible improvement of her appetite, and a few days later she ate, voluntarily, four times per day.

The wound, by this time, had become rosy in color and more active.

The patient left on July 7th, not cured of her osteitis, but her general condition had been changed in a wonderful manner. The mucous surfaces had assumed a promising rosy tint, although some cardiac murmurs remain.

Case XLII. *Caries of the Bones of the Left Foot; Profound*

Anœmia. Inhalations of Oxygen. Rapid Improvement.—John F., aged sixty-two, entered the hospital March 18, 1864.

This man has never been seriously ill. Six months ago was kicked in the lower part of thigh by a horse, from which followed a general tumefaction of that region, with heat and fever, which compelled him to keep his bed for a fortnight. Made an apparently fair recovery. Eight days ago he was seized with lumbago, cephalalgia, and fever, and was obliged to relinquish all business and take to his bed. Pain, rapidly increasing in intensity, located itself at the external border and the dorsal surface of the left foot. This region swelled rapidly, and a physician was consulted, who, thinking it a liquid collection, punctured it with a lancet, but it yielded only a little bloody serum. No relief. The symptoms at the side of the foot becoming more aggravated, and the fever daily increasing, the patient decided to enter the hospital.

We found him pale and greatly emaciated, his facies expressing intense suffering and pain. Foot much swollen, but no fluctuation; pulse rapid and feeble. No sleep, no appetite. Second-grade diet. Bordeaux wine, soups, and wine of cinchona; compression by means of a roller bandage.

March 22d. Lancinating pains in the foot, slight redness of the skin, deep fluctuation.

Incision, followed by the issue of nearly two spoonfuls of pus mixed with blood. Prescribed oxygen in doses of eighteen litres, with an equal proportion of air.

March 23d. The inhalations have not caused the pulse to vary; no effect on the vision; color of the lips not perceptibly changed; no tinnitus aurium; no change in the color of the wound.

March 24th. The dose is increased to twenty-five litres. The patient experiences light flashes before the eyes.

March 25th. Intense pain in the foot; scarcely any sleep; wound shows slight increase of color. Patient somewhat more lively; not so weak; appetite better.

March 26th. Pulse, before the inhalations, 80; after inhaling, 84. Appetite increased, the patient eating with relish.

April 1st. Appetite good; is allowed fourth-grade diet. Since the foot was dressed with a starch bandage, pain has been less; nights quiet, but not more than three or four hours' sleep at most; cardiac and arterial sounds normal. Respires twenty-

five litres of oxygen. Pulse, before inhaling, 80; after, 93; no disagreeable sensations following. Mucous surfaces show a little more color immediately after the inhalations.

April 5th. For two days the pains in the foot have been more acute; they are especially aggravating in the evening and in the nights, preventing sleep. Appetite now very good; countenance shows more color; eyes more brilliant. Gave him fifteen litres of oxygen; pulse, prior to inhaling, 84; immediately after, 88.

April 6th. Starch bandage removed. Inhales eighteen litres of gas. Pulse, before inhaling, 76; after, 80.

April 7th. Starch bandage replaced. Inhales fifteen litres of oxygen.

April 10th. Appetite has become very strong; wakes to eat in the night. He has more color; his strength begins to return; general condition much more satisfactory.

April 12th. Patient's strength rapidly returning; his appetite constantly increases. He not only eats four regular meals, but also takes two more given him by a neighboring patient. Sleeps well all night. Still suffers some pain in the foot. Oxygen, twenty litres.

April 18th. His general and local condition is very satisfactory. Use of oxygen discontinued.

In view of the virtues which we now know belong to oxygen, it was quite natural to undertake to benefit patients afflicted with cancer. This I have done very often with entire success, fully realizing that it would not cure. Certain cases have remained refractory under the use of this agent. I have been able with a number of patients to restore the digestive energies and to induce them to take substantial food, whereas everyone knows how frequently patients affected with cancer have an aversion to food.

Case XLIII. My first patient was an elderly lady, aged sixty-nine, who suffered from an ulcerated cancer of the breast. She was anæmic and debilitated. Oxygen so aroused her appetite that she awaited meal-time with impatience. She soon regained her natural color, and her strength was quite restored. Patient then left my care and I lost track of her.

Case XLIV. The sister-in-law of a former distinguished interne of the hospital, still young, yet suffering from an enormous cancer of the breast, which was not susceptible of being

removed by operation, was able, thanks to oxygen, to regain her strength and to return to social life for a year from the commencement of oxygen inhalations, in spite of the deplorable condition in which she was at the time she began the inhalations.

What I have just said concerning cancer of the breast I repeat with respect to cancer of the uterus. In these cases, however, when oxygen has succeeded it has revivified the patients, but I am compelled to say that it has not cured a single case.

Case XLV. *Anæmia from Cancer. Respiration of Oxygen.**—Mme. Anatolie T., aged fifty years, married, and the mother of several children, entered the City Hospital, June 8, 1865, for a disease of the womb.

Facies indicated cancerous cachexia. Complains of pains in the back, of heaviness in the uterus, and swelling of the limbs. At the outset she had a profound disgust for food.

The next day, on examination, M. Demarquay diagnosed an ulcerating cancer at the neck of the uterus. After a few days of rest and preparatory treatment, M. Demarquay proposed to destroy the tumor by caustics, and to this end he simultaneously inserted several pencils of chloride of zinc into the substance of the cancer. He also ordered inhalations of oxygen.

June 17th, patient inhaled twenty litres of oxygen, which dose was repeated the next day and for some days following.

At the end of three or four days the patient experienced a sense of well-being. No longer has disgust for food, but finds her allowance insufficient and impatiently awaits the hours for eating.

Several cauterizations were resorted to, at intervals, and anæsthetic douches of carbonic acid were administered, *per vaginam*, to allay the pain.

The patient's condition became much improved.

August 11th, the patient left the hospital. Her general condition was very satisfactory. Appetite completely restored.

The uterine tumor had disappeared, and no ulceration of that organ remained.

Every physician knows that disease of the genito-urinary organs is usually followed by a lingering convalescence, a condition of anæmia, and a dyspepsia difficult to conquer. In a

* Case recorded by M. Barlemont, externe on duty.

number of cases we have had great success with oxygen. In many emergencies it has restored the strength and aroused a really reparative appetite. The case which most impressed us was that of a brave soldier who had suffered for a long time with chronic cystitis, connected with a very hard stricture. Urethrotomy had improved his condition, but nothing availed to remove his anorexia. Under the influence of oxygen we saw, in a few days, his condition improve; appetite returned, and with it strength and good spirits. He left our care, still troubled with a slight cystitis which obliged him to urinate frequently, but his general condition was greatly improved.

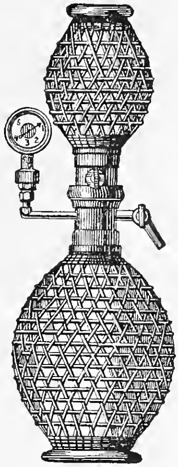


FIG. 9.—APPARATUS FOR THE ADMINISTRATION OF CARBONIC ACID DOUCHES.

We have likewise had recourse to inhalations of oxygen in spermatorrhœa. We have not completely cured any case, but have, with many, bettered their general condition, restoring the general strength and appetite.

Perhaps we should have been more fortunate had we added to the oxygen treatment the use of caustics and other means, which have proved efficient in certain cases.

We have had remarkably good results with oxygen, in restoring the strength and vigor of women long afflicted with uterine disease. Confinement in bed, in warm apartments, induces in them extreme anorexia and marked anæmia, the natural consequences of a lack of nourishment and assimilation.

In these cases we have seen oxygen, in a very few days, restore a new vitality, when iron and wine of cinchona had failed.

The following is a case in point:—

Case XLVI. *Induration of the Uterus; Chronic Metritis; Chloro-Anæmia Supervening. Tonic Treatment, with Inhalations of Oxygen.**—Mrs. Bertha J., a Hungarian widow, aged thirty-two, entered the hospital October 6th.

For several months this woman has complained of severe pains in the lumbar regions, in the lower abdomen and upper part of the thighs. She experiences dragging in the groins and weight in the pelvis.

She is habitually constipated. For four months her courses have been very irregular, sometimes very profuse, at others very scanty, staining the linen but for a day. At this time her sufferings are very intense; she is compelled to keep her bed, and has had constant cephalalgia for several days.

By means of specular examination and vaginal touch, M. Demarquay and the internes on duty determined that the uterine neck was hypertrophied, indurated, and engorged. It was scarcely possible to trace with the finger the circumference of the neck; the womb itself enlarged, indurated, and difficult to elevate.

No leucorrhœa, except for a day or two before the appearance of the menses. We did not practice rectal touch, since abdominal palpation sufficiently demonstrated the condition and position of the uterus in the inferior strait. The pressure used was very painful. Vaginal touch did not discover anything abnormal on the part of the broad ligaments, the ovaries, or the neighboring peri-uterine cellular tissue. The patient had a pale, yellowish color, no strength, no appetite.

M. Demarquay prescribed baths, wine of cinchona, poultices, rest in bed, and inhalations of oxygen.

From the 11th to the 23d of October, every morning, this patient respired about fifteen litres of a gaseous mixture (oxygen diluted with one-third air), then twenty, and finally thirty to thirty-five litres, the proportion of oxygen being increased from day to day.

This woman has a pulmonary capacity quite remarkable. She can inspire from two to three litres (one hundred and twenty-two to one hundred and eighty-four cubic inches) at an

* Case recorded by M. Lavaysse, externe on duty.

effort, whereas the average is but one litre (sixty-one cubic inches), at an ordinary inspiration.*

The following are the phenomena observed and recorded from day to day in this case: The first day fifteen litres of gaseous mixture was inhaled, in two minutes and ten seconds. The pulse rose from 68 to 76. The skin became moist with perspiration, over the chest, forearms, and hands; there was felt some warmth in the chest.

No headache, no intoxication, no constriction of the temples, no tingling of the fingers.

October 20th. The dose was increased to twenty litres, of which fifteen were pure oxygen. The pulse-rate increased eight pulsations; skin moist; the warmth, formerly limited to the chest, became diffused.

There was in the frontal sinuses, at the root of the nose, and in the temples, a sense of obstruction or oppression, which the patient compares to the obstruction preceding coryza.

On the 23d the dose was increased to twenty-five litres, the patient realizing with pleasure that her appetite increased from day to day. For from twenty minutes to one or two hours after the inhalations, she experiences an indescribable sense of well-being, which makes her very sprightly. There is a sense of gentle warmth in the chest, and a feeling of invigoration, which, however, soon passes away.

We suspended the inhalations of oxygen for three days, inasmuch as the patient declared that although her general condition was decidedly better, the pains in her loins and lower limbs were more acute, and severely tormented her, chiefly in the night.

On the 27th we again returned to oxygen. The dose of twenty-five litres was increased to thirty-five litres by the end of twelve days, twenty litres of each twenty-five being pure oxygen.

The pulse varied from 68 to 72, rising to 80 and 84, this being the maximum.

Her appetite increased every day, her strength rapidly

* If the author seriously means that a French woman's lungs have an average capacity of only sixty-one cubic inches, they certainly fall below that of the average American woman. My experience leads me to place the average lung capacity of women at about one hundred cubic inches. Many of my female patients have shown a capacity of one hundred and fifty cubic inches. In this country men average one hundred and fifty to two hundred cubic inches. I also recall two instances of the unusual capacity of three hundred and fifteen, and one of three hundred and thirty-five, cubic inches.—TRANS.

reviving; her facies improved; the lips and conjunctivæ, from being pale, became rosy, and the features assumed an expression of animation. This sense of well-being reached its maximum after three experiences, during each of which the patient inhaled twenty-five litres of pure oxygen. In the chest, behind the sternum, she felt a considerable degree of warmth, which disappeared at the end of one to two hours, following which respiration was more free.

From the 8th to the 16th of November the patient respired thirty to thirty-five litres of oxygen per diem, diluted one-fifth with air.

The same phenomena were repeated with increased intensity.

On three occasions there was a little transient intoxication, with a tendency to sprightliness and hilarity; also a little giddiness, flashes before the eyes, and at times a little ringing in the ears.

Tingling at the finger-ends; the skin becoming moist; pulse smaller, more firm, and increased in frequency from 4 to 12 pulsations.

There has never been any cephalalgia beyond a sensation of oppression or constriction in the forehead, which soon passed away.

The last two inhalations were given on the 15th and 16th of November, and consisted of thirty-five and thirty-eight litres respectively of pure oxygen. We observed the same phenomena as before, with still greater intensity, perhaps for the following reason:—

At the suggestion of M. Demarquay, before whom these experiments were conducted, we directed the patient to make long respirations and to retain the gas as long as possible in the lungs. At each of these two efforts the patient retained the gas in the lungs for from ten to thirty seconds, that is to say, she made but three to six inspiratory movements per minute, the normal rate being eighteen. By this means the gas was more fully taken up by the blood, from remaining longer in contact with it.

We add a rapid *résumé* of the observed phenomena: A sensation of decided but not unpleasant warmth in the chest; acceleration of the pulse, and also of the respiratory movements; moisture of the skin, which feels warmer to the hand; slight momentary intoxication; flashes before the eyes, and ringing in the ears. In a word, and to conclude, after nearly six weeks of

oxygen inhalations, this patient has regained color, good appetite, and a restoration of her strength; this convalescent, a valetudinarian, has gained much; her disease was much improved, and her general appearance, in particular, was very much better when she left the hospital, November 28, 1863.

We could multiply the reports of uterine diseases in which the use of oxygen has been found very useful; but in these cases the gas was always administered to combat dyspepsia and anæmia, which are so frequently the morbid elements complicating chronic diseases of the uterus,—a point on which M. Beau has so strongly insisted; besides, we desire to conclude this summary of surgical diseases in which oxygen has seemed to us to be useful by publishing a case borrowed from Beddoes. We give this case more particularly for the reason that in the troubles so common to menstruation we have personally never administered oxygen gas:—

Case XLVII. *Chloro-Anæmia, Dysmenorrhœa, Supplementary Hæmorrhages, etc., Treated with Oxygen. Recovery.*—"The subject of this report is a young woman who constantly presented symptoms of chlorosis; the monthly flow being scanty and of a serous nature. She was married, and has several times been pregnant, with each time a bad confinement.

"Several years since herpes of the face appeared, and in the surrounding cellular tissue some extravasation of blood followed, with engorgement of the capillaries. These patches of extravasation have given rise to hæmorrhages of such frequent occurrence that the patient, according to my estimate, has lost as much as thirty ounces of blood in a week, and seldom less than six or seven ounces.

"Assuming that this resulted from insufficient menstruation I gave numerous uterine stimulants, but without effect.

"Iron gave some increase to the general tone, but at the same time equally increased the capillary hæmorrhage of the face.

"Treatment by mercury and other known remedies, and even the topical application of astringents and further use of stimulants, proved of no avail.

"In view of a similar case, and seeing that the hæmorrhages were becoming more frequent and more profuse, I commenced the administration of oxygen, following the usual method. I soon saw a considerable improvement in the chloro-

anæmic symptoms. The suffocation and œdema of the limbs, which had persisted in a remarkable degree, had gradually disappeared, and sleep had become much more refreshing. At the end of a month of treatment, during which I administered three to four gallons of diluted oxygen, three times a day, the skin assumed color, indicating a better state of health, and the enlarged capillaries and ecchymoses of the face began to disappear. The hæmorrhage was so much lessened that I deemed it necessary to provide another issue to prevent symptoms which might follow the abrupt stoppage of such a considerable loss of blood, which had now become habitual. This was the only additional treatment given; and in order that results to which it was a stranger may not be attributed to its auxiliary action, I ought to state that I did not prescribe it until after the improvement of the patient had already become most conspicuous; moreover, the same remedy previously used by itself had produced no such results.

"I continued the administration of the same quantity daily for three months, with a steady improvement on the part of the patient, although the hæmorrhage had never entirely ceased. Treatment was then suspended, with the idea that the habit would finally cease by gradually losing its force. Her health continued to improve, and the malady gradually disappeared.

"The following are the more important conclusions which may be drawn from this report:—

"Under the influence of oxygen the pulse became more full, more frequent, and stronger; the temperature of the body was increased, but not the hæmorrhages, as had been the case when iron was administered, in connection with exercise and a nourishing diet. To explain the effects of oxygen we may adopt the opinion of Mr. Hunter, according to whom activity and strength are essentially different; and oxygen is one of those rare stimulants which affords at once both strength and stimulation. We can also, after some of the most modern physiologists, assume that oxygen contributes to the organism a certain degree of irritability, and thus becomes a source of excitation. This opinion seems confirmed by this case, since oxygen rendered the system more sensitive to other stimulants, such as purgatives, for example, as I have repeatedly satisfied myself in certain other cases. THOMAS CREASER."

[Referring to the "issue" which Beddoes deemed it well to create in his patients, lest the sudden suppression of an habitual hæmorrhage might result in damage to the system, in these later days, and with our present knowledge of pathology, a majority of intelligent practitioners would promptly disagree with the Oxford professor. It is not now considered dangerous to check at once any active, or even passive, hæmorrhage from any part of the body. In fact, it has been satisfactorily demonstrated that the average menstrual flow is in excess of the physiological need, and that effectually checking it by means of astringents, and even the tampon, as soon as it seems in the least excessive, or even moderately profuse, is not only not injurious, but is a decided benefit, in that it prevents a useless loss of blood, thereby conserving an equivalent of strength.—TRANS.]

CHAPTER V.

NITROGEN, MONOXIDE OF NITROGEN, AND HYDROGEN.

I. GENERAL REMARKS.

WE are often asked,—and this reflection should occur to the minds of many physicians,—how does it happen that the gas most abundantly diffused in nature, nitrogen, has not been the object of more frequent investigations? How happens it that nobody has had more curiosity regarding the fluid which constitutes very nearly four-fifths of the atmosphere in which we live? This is evidently one of the inexplicable laches which are met at every step in the history of the sciences. When once the exact composition of the atmosphere had been established, that nitrogen is unsuited for respiration, and, consequently, for the maintenance of life, and that the name which it bears (*azote*) is by no means characteristic of its properties, it was thought that all had been said that could be said on the subject, and that there was nothing further of interest in it.

But what is the meaning of the expression *unsuited to respiration?* Carbonic acid, without being really toxic, is also *unsuited to respiration.* Hydrogen shares this property, without being any more poisonous. Thus, there are three different gases which present these two common characteristics; and yet who is bold enough to affirm that they have absolutely the same properties? Their action upon respiration, apparently identical, rests upon this fact, that they constitute an atmosphere deprived of oxygen, and it is known that life is utterly impossible, beyond a few moments, without the presence of the latter gas. But apart from this lack of the vital quality, it is evident that each of these gases exercises a special agency, possesses some degree of influence on the human organism which is proper to it. Here, we are gratified to remark that surgical practice has been for us an excellent guide, and has furnished us, relatively to the physiological action of this gas, a criterion which physiological experimentation, very probably, will only corroborate. Nevertheless, before touching upon investigations of the gases personal to ourselves, we oropose to re-investigate nitrogen, protoxide

of nitrogen, and hydrogen. It may be well to mention, briefly, the works, for that matter very few in number, published upon this subject.

II. NITROGEN.

At the end of the last and at the commencement of the present century, nitrogen had been the subject of two monographs, of which it is now impossible for us to appreciate the relative importance, the library of the faculty containing neither of them. The first,* published in 1796, in New York, is known to us only by the account of it given by the British Library,† as well as by the "Annales de Chimie."‡ It appears to us, moreover, to be full of views purely hypothetical, some of which do not rest upon any well-demonstrated fact, and the rest of which are entirely at variance with established scientific principles. As to the rest of the work, this is the way the author constructs his monograph, his *Septon* medical system, according to the article in the "Annales de Chimie":—

"The author thinks that the putrefaction of animal substances has a period in which the nitrogen, at the moment of disengagement, finding itself in contact with oxygen can combine with it without the need of a very high temperature. The oxide of nitrogen thus formed is capable of becoming a very active poison, so that cancer and the whole family of rodent ulcers have, perhaps, no other origin. Miasms from nitrogenous substances which putrefy in the marshes, in prisons, in moist and hot climates, form, according to the hypotheses of the author, a certain chemical combination of nitrogen with oxygen, which becomes the cause of contagion and of many endemic and epidemic diseases, etc."

It is easy to see, from the foregoing account, how debatable are the theories of Saltonstall, or, rather, it is seen that they do not rise above the domain of hypothesis, or pure speculation. Moreover, this author has done no more in this initiatory dissertation than to amplify ideas advanced by Mitchill, his master.§ We will not dwell longer on this work, which has no other than

* An Inaugural Dissert. on Chem. and Med. History of Septon [nitrogen], by Winthrop Saltonstall; 8vo. New York, 1796.

† Section of Sciences and Arts, 1796.

‡ Vol. xxii, pp. 96 and 97, 1797.

§ Mitchill, Remarks on the Gaseous Oxyd of Azote, etc., and upon the Effects which it Produces when it is Engendered in the Stomach, Inspired into the Lungs, and Applied to the Surface of the Skin; 12mo. New York, 1795.

an entirely incidental relation to nitrogen. It seems, however, perfectly natural that from the United States should come to us the most important and the most numerous researches upon this gas, since in certain parts of that country there are abundant springs of perfectly pure nitrogen, as indicated in the following note.*

The other monograph to which we have made allusion is that of Dagoumer,† of which the title promises more interesting study than that of the American author; but that is all we can say of it, notwithstanding our desire to do more than to merely mention it. It is probable, however, that this work must reflect, to some extent, perhaps even amplifies, the ideas to which the scientific physiological investigations of Nysten, concerning the gases, had given impulse.

It was really at this epoch that the friend and collaborator of Bichat pursued his studies upon the action which various gases, injected into the circulatory system, exercise upon the organism. We have had more than one occasion, in the course of this work, to refer to and discuss the experiments of Nysten; hence we will not now revert to the subject. We will only say, as to the gas under consideration, that Nysten, by injecting nitrogen into the veins, believed that from it he recognized a sedative action upon the heart. It would be important to verify this fact, and, if later experiments confirm it, we shall have thus acquired a therapeutic agent as much more valuable as it is more abundantly diffused.

Since Nysten, no one, to our knowledge, has specially occupied himself with nitrogen. The paragraphs which Merat and de Lens devoted to this gas, in their "Dictionnaire de Thérapeutique," are as apt to-day as they were in 1829. This is, in sub-

* The nitrogen springs most remarkable in the county of Rensselaer are those found to the southwest of the village of Hoosic, at a distance of about six miles south from the village of Bennington, Vermont. There are three springs within an area of about four or five acres of land. The quantity of nitrogen gas which escapes under the form of bubbles is incalculable. This gas does not appear to be combined with water; it seems to rise from the gravel which forms the soil of the springs. The disengagement of the gas is not limited to this place. It escapes continually from dry portions of the surrounding soil. Its presence manifests itself only when water covers the soil, by the kind of boiling it produces in escaping through it.

By compressing a surface of gravel equal to five or six inches square there may be collected in a bottle or inverted bell a litre of the gas, in the space of ten seconds.—[Journal de Pharmacie, vol. ix, p. 120, 1823; from the Edinburgh Philosophical Journal.]

† Dagoumer, Essai sur le Gaz. Azote Atmosphérique, Considerè dans ses Rapports avec l'Existence des Animaux, etc. Paris, 1816.

stance, what those authors then said: "The medicinal uses of nitrogen are null, or scarcely noticeable. It has been thought that the inspiration of this gas, always mixed with a certain proportion of oxygen, might prove useful in certain chronic diseases of the chest, and they cite two cases of phthisis, reported by M. Marc, in which he produced a lowering of the circulation and freer expectoration. Nysten always considered it as indicated in the more acute diseases of the respiratory organs."

Since then scientific researches with regard to nitrogen have changed the ground but little. One is certainly interested to learn the rôle which this gas plays in the organism when absorbed in the condition of atmospheric air, and also in the form of alimentary nitrogen. It would doubtless be very interesting at this point to study its physiological destination in the animal economy, to elucidate more completely the function which devolves upon it in respiration, and especially in the general nutrition—all questions upon which we are far from being perfectly settled. But, as this volume has already grown to considerable size, and has even exceeded the limit which we originally designed to give to it, we will not venture into a study of pure physiology or of chemical physiology. Therefore we limit ourselves to an exhibition of the history of nitrogen in a surgical point of view.

In the chapter on the gases of the blood we have reported all the experiments by the aid of which it has been sought to demonstrate that it penetrates into the blood during the act of respiration. We will not recur to that subject. In the pages which follow we propose to show the result of the experiments and of the labors that we have undertaken with M. Leconte, having for their object—first, to see what becomes of nitrogen when it is introduced either into the cellular tissue or into the peritoneum; second, to determine the action it exerts upon the movement of the pulse when placed in contact with the same tissues. These researches will only be summarized here.* In reality, notwithstanding the care and zeal we have given to the pursuit of them, the results are yet insufficient to warrant conclusions; nevertheless, they should always be taken into consideration. The preparation of nitrogen presents serious difficulties, time being necessary to obtain it pure. I have even sometimes interrupted an experiment already commenced on

* Etudes Chim. et Phyol. des Gaz. Inject. dans les Tissus Vivants et Mis en Contact avec les Plaies (Arch. Gén. de Méd., 1859).

account of impure gas. Nevertheless, those experiments have appeared to us to be worth reporting; for, repeated with care, they may lead, perhaps, to results of practical importance.

In the memoir just referred to it is shown that we have obtained, by injections of nitrogen into the peritoneum and the cellular tissue, this curious and interesting result,—that the injection of nitrogen into the cellular tissue and the peritoneum provokes a greater or less exhalation of the gases of the blood, oxygen and carbonic acid, of which the quantity varies, especially the oxygen, according to whether the stomach is empty or in full process of digestion. We will give to these experimental results no further attention. For further details we refer to the paper on this subject published in 1859.

We have demonstrated, in studying the topical action of oxygen and carbonic acid, that these two gases have a stimulating effect upon wounds, and that in contact with the latter, especially if not atonic, they excite a more or less lively reaction.*

We have concluded, from our experiments upon animals, and, later, our studies upon man, that nitrogen is, in a manner, the mere solvent of oxygen, and that of itself it has no active properties; further, that the irritating properties of air, as regards wounds, recognized by Monro and Hunter, and more recently by surgeons who have made a special study of tenotomy, are due to oxygen. If these speculative views are corroborated we shall have then found in nitrogen the demonstration of one of the greatest problems which confronts the modern surgeon, that is to say, the reunion of wounds by first intention by placing them under entirely new conditions, which will maintain, in the work of repair or adhesion, a degree of activity or excitation which will not exceed certain limits. But, it will be said, that is only a hope, which is true; nevertheless, let us declare at once that we will endeavor to realize something from these new conditions, in which no experimenter before us has placed himself. This object, for which we undertook some experiments many years since, in another way, has actively occupied the mind of one of the most distinguished surgeons of our time. We allude to M. Guerin. We have witnessed one case where the application of the method of this surgeon has realized, in a physiological

* See our second essay, Reparation des Tendons dans les Tenotomies Sous-Cutaneus, sous l'Influence de l'Air, de l'Oxygene et de l'Acide Carbonique (Arch. de Méd., 1862).

point of view, the end which he desired to attain. Perhaps there will be deduced from these various studies a practical fact which will avail something for the relief of the afflicted and toward the progress of surgery. Besides, the attempts made by M. Leconte and ourselves may be readily repeated. It is only necessary to have the nitrogen. The operation being done, the limb, upper or lower, is placed in an India-rubber apparatus, a kind of muff or boot, of which the cuts on pages 152 and 153 will give a practical idea. With the apparatus illustrated by Fig. 7 less gas is necessary, but it compresses the parts a little more, and may sometimes impede the circulation. This apparatus, properly applied, is filled with nitrogen. We have studied the employment of this gas in a double point of view; first, from the point of view of original disease, and, second, from the point of view of the reunion, or, rather, the work of reparation of wounds. First, can we quiet the pains inseparable from all operations performed upon an organized and living part? By chloroform we remove momentarily the sensibility, but, chloroform having ceased to act, the pain, often very intense and very lasting, returns. It cannot be said with certainty that the pain which follows all operations is a result of contact with air, for in this case all subcutaneous operations, properly made, ought to cease to be painful as soon as terminated; but, unfortunately, it is not so. The operation finished, there remain nerve-trunks which are bathed by the blood; besides, there is the reaction which always follows from every operation. If, then, all surgical operations involving division or cutting of tissues are inevitably painful, it remains to be determined whether it is not possible to moderate this pain. Many attempts have been made in this direction. Various narcotic substances have been applied in the form of fomentations. M. Jules Roux, of Toulon, prescribed chloroform-spray, basing his theory, doubtless, upon the experiments made by Flourens and Longet relative to the action of chloroform applied directly to the nerves themselves. But, unfortunately, this substance, applied to the tissues, and even upon the integument, excites active irritation, even to the extent of blistering. Nitrogen has not this objection. The following report summarizes the experiments which we undertook, in conjunction with Leconte:—

We will quote first the particulars of a case reported by Lemoine, a prominent interne of the hospital:—

Case XLVIII. *Employment of the Nitrogen Bath after Disarticulation of the Little Finger.*—The operation was performed without chloroform. Slight hæmorrhage; no ligature required. After the operation the arm was immediately placed in a hood of India rubber, made air-tight above the wound by strips of adhesive plaster, which closed it hermetically; it was emptied of air and refilled with nitrogen. The patient, who was suffering severely, experienced considerable diminution of the pain; he complained only of prickling and of a sensation of numbness. The operation was performed March 8, 1865.

Case XLIX. March 4th of the same year we removed the right forefinger from a patient aged sixty-five years. Immediately after the operation, during which the patient had been anæsthetized, the hand and forearm were placed in a suitable hood and nitrogen applied. The patient felt little pain. In two hours he thought he felt hæmorrhage from the wound. The apparatus being removed, he at once experienced sharp pain, more severe, in fact, than that which followed the operation. The member was replaced in the apparatus, and the next day he said he had passed a good night and suffered but little.

Case L. On the 16th of April, same year, a patient, aged twenty-three years, entered our service to be treated for phlegmon of the right hand. He complained of severe pain in the right hand and forearm. We placed the hand in a balloon filled with nitrogen, and the next day the young man was still suffering, but felt the pain less severely.

In two other cases we were less fortunate. After amputation at the knee, in one case, and in another resection of diseased tissues of the foot, the patients complained of severe pains. Perhaps in these cases the gas was not pure, or the apparatus may have been badly applied; but the fact remains the same, and must, like favorable ones, be recorded, that in these two last cases our hopes were not realized. Notwithstanding their failure, we have felt it a duty to make known these cases, proposing to ourselves to again take up this study in the near future.

Another more interesting case we here publish in full, as observed. In this case we assert that nitrogen was not used as a mere negative or isolating agent, incapable of producing any effect upon wounds. We have applied it daily for eight days, in contact with an extensive recent wound, and at the end of that time this wound had not made the usual progress expected of

all wounds at this stage of their history. It was then placed in a muff, filled with oxygen, and at the end of twenty-four hours a notable change was observed, and soon it was covered with healthy granulations. This case, unfortunately unique, in which we have been able to apply nitrogen in a continuous manner, makes us hope that we may be able in some way, thanks to the isolating action of the gas employed, to obtain, in some cases, union by first intention, a result often quite difficult. Our purpose is not to interrupt the progress of reparation; even if it were desired, it would be impossible to arrest it by topical applications. There is an inherent effort of nature which operates unceasingly, and is as much more rapid or intense as the individual is more healthy and less debilitated. What we should strive to do is not to check the work of reparation, but to remove, if possible, the exciting causes which the air itself may interpose to delay this work, and to prevent a too active inflammation, which will prove injurious to the patient.

Case LI. *Cancerous Ulceration of the Knee. Excision; Applications of Oxygen and Nitrogen.**—Madame B. entered the Maison de Santè 20th January, 1863. Age, sixty-eight. She has always enjoyed good health, despite the exhaustive labors to which her occupation of laundress exposed her. She had ceased to menstruate at the age of fifty-two.

About fifteen months before her entrance into the hospital she noticed, near the middle of the patella, a roundish tumor, painless on pressure and in walking. She was not alarmed, and continued her habitual labors. At the end of two or three months this tumor, which had already acquired the size of a nut, became painful. The skin exhibited no change of color. The patient noticed, a little later, that the base of the tumor seemed to extend more and more, and that the surface became shining, soft, and streaked with bluish lines which interlaced in all directions.

Early in December a small ulcer opened in the centre of the tumor, suppurating profusely, and instead of cicatrizing, spread more and more in all directions.

When we examined it we found an oval tumor, having its greater diameter in the direction of the knee, in length five and a half centimetres [about two and one-sixth inches]. The lesser diameter was three centimetres [about one and one-fifth inches].

* Recorded by Flurin.

The tumor was movable and very hard. It had ulcerated over three-fourths of its surface. The base of the ulcer presented bluish-red granulations disagreeably soft to the probe and bleeding at the slightest touch. The edges were hard and had a livid tint. The skin in the vicinity of the tumor was normal.

Dressed with glycerated lint. Tonics; baths.

January 25th. Application for three hours of a hood containing oxygen. When withdrawn the aspect of the ulcer was sensibly modified; it presented a much more vivid color; the granulations at the bottom seemed better defined; abundant sero-purulent discharge from the whole surface. The application of the gas revived the pain, which from being intermittent became constant. Fresh glycerin dressing.

January 27th. Fresh application of oxygen for twenty-four hours. The ulcer has now a healthy appearance. Suppuration profuse; the edges have no longer the livid aspect which they presented at time of entrance.

February 1st to 20th. Oxygen applied every day; but during two days the pains were so violent that carbonic acid was substituted for oxygen. Notwithstanding the ulcerated part was in good condition, the tendency of the tumor to spread and its hardness decided M. Demarquay to incise it.

February 20th the operation was performed. In place of the bistoury we used a platinum electrode heated by an electrical current to a temperature of 1500° C. (?) [2732° F.]. A slight hæmorrhage during the operation necessitated ligature of some small vascular trunks. Immediately after the operation the member was placed in a hood containing nitrogen. At evening, on removing the apparatus, it was found that the patient had lost about two hundred grammes [about seven ounces] of blood. Should not this hæmorrhage be attributed to the presssure exerted by the hood above the wound, which pressure must oppose return of the venous blood? Beyond this the wound shows nothing special.

February 21st to March 1st. Every day the knee was placed in a hood of nitrogen. The wound remained many days stationary, that is, there was no apparent work of repair. It remained covered with a plastic exudation, but there was no other trace of inflammation which might lead to the development of granulations.

March 2d. Application of oxygen.

March 3d. The wound, examined, shows a brighter color at the edges. The surface is no longer uniform, as formerly. Oxygen continued.

March 4th. Some small inequalities developed yesterday upon the surface have all at once the appearance of granulations; they are more rosy in color and exude pus. The pain is more acute at the centre of the wound, and there is a very decided sensation of heat in the whole member.

During these last three days oxygen has been applied only two hours. Analysis of the gas removed was not made by Leconte.

From the 4th to the 23d simple glycerin dressings. The wound continues to grow moist, and takes on all the character of a solution of continuity progressing toward cicatrization. The edges are beginning to be covered with a bluish membrane. Dressed by occlusion with small adhesive strips, removed every five days, until April 14th, date of the discharge of the patient. There remained then only a surface of the diameter of a one-franc piece not cicatrized.

We see by the preceding case the influence of nitrogen upon a simple wound. The result noted in the following case is not less interesting, since it illustrates a comparative experiment with nitrogen and oxygen:—

Case LII. *Ingrowing Nail. Application of Nitrogen. Moderation of the Pain.*—J. M., age twenty-one years, employed in trade, had been operated upon February 13th for an ingrowing nail, with which he had been affected since one year old. Local anæsthesia was produced by means of a refrigerating mixture of ice and sea-salt; after which, the nail having been split with flat scissors lengthwise in the middle, each half was successively evicted by means of ordinary forceps; matrix then dissected and removed with a small section of the outer portion of the ball of the toe.

The operation was painless. Fifteen minutes later very severe pain in the great toe. These pains persisted about two hours. Dressed with cool water during three days, 13th to 16th. During these three days the patient experienced, from time to time, moderate pains.

From the 16th to the 21st, application of nitrogen boot, renewed morning and evening. No more pain after application of the nitrogen. We could also say that the wound was not in

the least inflamed. In place of the bright-red granulations which precede cicatrization, there was seen only a grayish or whitish surface covered by a false membrane.

The 21st. In order to compare the effect produced by oxygen with that following the use of nitrogen, the knee was encased in a boot of oxygen during about three-quarters of an hour. At the end of this time the boot was removed, and the wound presented an aspect very different from that of the preceding days. The grayish color had given place to a delicate red; it was studded with pale-red granulations protruding from the surface. Moreover there was no pain.

Resumed the use of nitrogen.

22d. Removed the boot containing nitrogen. No pain.

The edges of the wound were slightly red; the centre, that is to say the place normally occupied by the nail, has become covered with a false membrane of grayish-white color. No swelling, no pain.

26th. The wound, washed freely with water, shows some granulations partially developed. No pain.

27th. Inflammation much moderated. The granulations are sluggish, although this is the fortieth day since the operation. The toe, the patient says, causes no suffering; it seems to him that he has no wound. Glycerin dressing.

March 2d. The whole wound is covered with granulations. Glycerin dressing continued.

We repeat, in closing, that these cases are not to be accepted as conclusive; but they warrant the hope that, with suitable apparatus, and with nitrogen carefully prepared, we may be enabled, first, to moderate the inflammatory reaction of wounds; second, to favor union by first intention.

III. PROTOXIDE OF NITROGEN (NITROGEN MONOXIDE).

It was Priestley who, in 1776, had the honor to discover the protoxide of nitrogen; this gas, the curious physiological action of which is so well worthy of our attention.

It is to be remarked that, possessing some of the chemical properties of oxygen, the protoxide of nitrogen has experienced, in medicine, very nearly the same fortune as "vital air." Imperfectly studied, or, rather, examined principally with reference to its composition and its chemical reactions with other substances, it suddenly emerged from its obscurity and assumed the

position of a wonderful agent. But the enthusiasm of English savants did not find in France many partisans, and finally, the medical employment of this gas, which had its brief hour of vaunted efficacy, was soon relegated to the rank of therapeutic eccentricity.

Not having made new experiments upon the physiological influence of protoxide of nitrogen, we have no inclination to favor its authoritative restoration to the formularies; but, perhaps it will not be useless to review such results as respectable scientists have obtained, either upon themselves or upon other persons, by the aid of this gas, in order to see if there be not means of deriving from it a better practical use than has yet been done. Sir Humphry Davy, who had accepted from Beddoes the chemical direction of the Pneumatic Institute, certainly could not better acquit himself of his functions than by studying the effects of this gas on the human organism, and especially those effects which were as yet little known. The curious properties of the protoxide of nitrogen at once impressed him, and he made it the subject of careful investigation, of which he published the results in 1800.*

Hardly had the exhilarating and anæsthetic action of protoxide of nitrogen become known, when everybody was curious to inhale the gas, and to try to experience the agreeable sensations which it produced; hence, there were *séances* of pneumatic chemistry, more curious and agreeable than serious or scientific, and for which there was shown the greatest enthusiasm. The celebrated paleontologist of Geneva, Pictet, from a journey made in England at this period, has left us a very interesting account of a *séance* of this kind at the Royal Institute, at which his friend, Count Rumford, induced him to assist.

We will give the words of the Genevese naturalist:—

"Davy submitted himself first to the trial, which to him was quite familiar. I observed him with much attention. At the third or fourth inspiration I saw him grow pale, and his lips took a violet tint; the action of the chest became more and more frequent and violent, and toward the end he inspired and expired all the contents of the bladder. The muscles of his face were working; one would have said that he suffered; he

* Chemical and Philosophical Researches, Principally upon Nitrous Oxide and its Respiration, by Humphry Davy, Professor of Chemistry to the Royal Institute. 8vo., 580 pages. London, 1800.

required a large quantity of it, as it seemed. Finally, he released the bladder, and, after a moment of ecstasy, he arose from his seat and traversed the parquet, smiling so good naturedly that the burst of laughter became general; he stamped his foot, swung his arms, and appeared to crave muscular action. These effects lasted only a few minutes, after which calmness gradually and insensibly returned. He described to us the entire train of sensations which he had experienced as being very agreeable.

"An amateur came next. I observed the same outward appearances that I have just described, but at the end of the inspirations he manifested a degree of agitation, which increased so rapidly that the others sought to make him release the bladder. He, however, retained it obstinately with one hand, while he compressed his nose with the other; finally they forcibly took it from him. He remained in a state of ecstasy upon his seat, raised his eyes to heaven, and continued to hold his nose, in a most grotesque attitude. A round of laughter from the entire assembly did not disturb him. At last he arose, laughing heartily, perfectly satisfied with what he had experienced and still felt.

"Another amateur presented himself. The first effects were the same, except that the agitation was still more marked. When it was at its climax, they took the bladder from him, but he did not relinquish it willingly. He afterward arose and began to walk the parquet, reeling, and with great strides. Before he could be caught he fell full length upon the carpet, insensible. They raised him; he recovered his senses in a few seconds, and was astonished at our appearance of concern on his account. 'I am very well,' he said to us, 'I am perfectly well, only I have a slight pain in my hip. I don't know what it comes from.' We knew better than he; it was the effect of his fall. In a little while he regained his natural condition."

Pictet thus relates the second *séance*:—

"There were five or six of us inclined to make the trial, and, out of courtesy to me as a stranger, they accorded me the making of the first trial. At the third or fourth inspiration, I experienced a rapid series of sensations, new to me, and difficult to describe. The principal effect was in the head; I heard a roaring; objects around me were exaggerated; it seemed to me that my head rapidly enlarged. I saw only as in a fog. I thought to quit this sphere and to raise myself in the empyrean;

I was everywhere at ease. By an afterthought that I distinctly recall, I felt that my friends were around me, and Count Rumford in particular, who observed, as we had previously agreed, the movement of my pulse, which became irregular in the extreme, insomuch that it was impossible to count it. I ceased then to respire the gas, and entered into a state of calmness, approaching languor, but extremely agreeable. Far from being inclined to muscular activity, I avoided all movement. I experienced in an exalted manner the simple consciousness of existence, and desired nothing more. In a few moments I returned to an entirely natural condition. Mr. Blackford succeeded me; his was an entirely different experience. First, extreme activity, which became almost convulsive; then boisterous gayety, soon followed by a more quiet enjoyment, and finally a return to normal.

"Davy succeeded Blackford. I observed his pulse myself, which acted in an extraordinary manner, sometimes very slow, sometimes excessively frequent. He experienced, otherwise, precisely the same effects which we had felt,—great exhilaration, disinclination to move, etc.

"Dr. Wollaston followed. He experienced effects very similar to those I felt, only more intense, imitating the same movement in both hands that one makes in stroking in succession all the finger-ends against the thumb. He moved them thus, gravely, during the paroxysm of languor, without any embarrassment from our bursts of laughter. His pulse was extremely irregular.

"M. Tighe was the next subject. He was not of the languid class. His agitation became so great toward the end of the inspirations that they wished to take the bladder from him; he retained it with all his strength, and when it was exhausted he began laughing and talking with much vivacity. He said that in all his life he had experienced nothing so agreeable.

"Mr. Blackford wished to try it a second time. He had no convulsions, but the gay paroxysm was quite pronounced.

"Dr. Wollaston wished also to make a second trial, varying the method. In place of making a certain number of inspirations and expirations successively into the bladder, he limited himself to a single inspiration, which he kept as long as he was able to retain it in his lungs. He would have held it longer had it not been for the desire to laugh, induced by the

influence of the gas, which he could not resist. He experienced the same sensations as during the first trial, and in both there was profuse perspiring.

"I repeated upon myself the experiment by the same process, and I obtained the same effects that I had experienced by the other method.

"M. Chenevix, the experienced chemist, came next. He was found to be of the active class; however, in a less degree than we had observed in the other persons affected the same way. The pleasure he experienced was neither preceded nor accompanied by any disagreeable sensation, and he spoke of it with a kind of enthusiasm.

"Count Rumford terminated this curious *séance*. He experienced nearly the same effects as Dr. Wollaston and I did, and, in addition, for some time after the experiment terminated, felt a strong inclination to sleep. All noticed that the gas had a sweetish taste." *

All these experiments, it may well be surmised, excited the most lively curiosity. In all quarters of the globe analogous experiments were tried. Mitchill, in the United States; Pfaff, at Kiel, in Russia; Wurzer, in Germany, and others, repeated the experiments of Humphry Davy, and obtained effects nearly identical, varying in intensity, according to the degree of susceptibility of subjects. Up to this time there was general concurrence of opinion, recognizing in protoxide of nitrogen almost complete harmlessness, based, as was well understood, on condition of not abusing it, or using it in excess. But in France this gas passed through the same ordeal of criticism to which oxygen had been subjected. It was not considered as harmless as had been claimed. Vauquelin and Thenard, who prepared both gases, and some other persons experienced accidents, though without serious consequences, which were nevertheless rather alarming, and tended to cause this gas to be considered as sometimes dangerous, so that its use was placed under proscription.

How explain results apparently so contradictory? It is manifest that a substance, harmless on the other side of the Channel, could not become dangerous by crossing the Channel. Moreover, we are of the opinion of Berzelius, whose description we quote, and in which may be found a very clear and accurate restatement of the physiological action of protoxide of nitrogen,

* British Library (Sciences and Arts), vol. xvii, p. 407 *et ultra.*

with an explanation of the accidents which may occur from its administration :—

"Animals and men who breathe this gas experience a sweetish, agreeable, but peculiar taste, which seems to pervade the lungs. When it is inhaled free from atmospheric air, and if, before breathing it, the lungs have been well emptied of air, one falls into an agreeable intoxication, which lasts one or two minutes, and which disappears without leaving injurious consequences. The intoxication may amount to loss of consciousness, if the inspirations are much prolonged. Aside from this, it has not been observed that the gas exercises any injurious influence upon the health, and the unpleasant effects noticed by certain experimenters have resulted from the presence of chlorine in the gas, as a result of using an impure salt to prepare it, or from nitric oxide, which may be evolved either when too great heat has been used in the preparation, or when the salt contains argentic or cupric nitrate. In all cases it is necessary, before submitting it for inhaling purposes, to take a little of the gas into the lungs, to make sure that it is exempt from chlorine and nitric oxide, the presence of which reveal themselves immediately by a disagreeable roughness, or even of constriction in the fauces and trachea.

"In general, it should be the rule that impure gas, as a result of faulty manufacture, should not be inhaled, since it is not certain to be *purified* by washing, so that it can be inhaled without injury. The property it has of exhilarating has given it the name of *laughing gas*. It is absorbed by the blood, to which it communicates a purpurine color.* A small proportion of this gas is decomposed in respiration. An animal confined in it dies by prolonged effects of the intoxication." †

The physiological action of protoxide of nitrogen did not long remain merely a curious chemical experiment. It was very soon thought feasible to utilize its properties in therapeutics; the first idea being to apply it to the treatment of diseases characterized by the impairment of the vital functions, which this gas seemd to overexcite. Beddoes, it appears, prescribed

* This "purpurine" color was not due, as has been thought, to the method of inhaling the gas over and over from bladders, from which fact carbonic acid was presumed to be the active factor. The blood actually assumes a distinct purplish tint and retains it for some time, as has been determined by causing the gas to be inhaled in considerable quantities prior to surgical operations involving hæmorrhage.—TRANS.

† Berzelius, Treatise on Chemistry, translated by Esslinger, vol. ii, p. 49.

it in a case of paralysis, but we have not been able to refer again to the place in his works where it is further discussed. Humphry Davy subjected himself at one time for a week, and at another time during two consecutive months, to the daily use of this gas, by inhalation, three times a day, and experienced from it a decided feeling of comfort. That which impressed him most forcibly was a general exaltation of all the functions, particularly of those sensations which are manifested by perceptions clearer and brighter than ordinary. He also found in this gas the first general anæsthetic which had been brought to light. He said, in substance, at the end of his work: "The protoxide of nitrogen appears to have, among other properties, that of annihilating pain. It might, perhaps, be employed with advantage in such surgical operations as are not accompanied by a great effusion of blood."

Riadore, who also made a special study of this gas, ascribed to it all the properties and the same influence upon the organism which Davy had described; but he studied it more especially from a therapeutic point of view. This part of his book is the most novel and most interesting. Here, in fact, he does not limit himself, as in the case of vital air, to reporting the opinions and doings of others, supported by two or three personal observations, as he did at the end of the account of oxygen. He appears to have employed protoxide of nitrogen in a large number of cases, and generally with success. The various affections of the nervous system are those for which the gas has oftenest been administered, but many other maladies have been treated with good results. We dare not place entire reliance upon the good results thus claimed by Riadore, but we hold ourselves open to conviction, notwithstanding the fact that the observations cited in support are far too incomplete to be conclusive to the mind of every one. For this reason we will quote no more of them here, at the same time asking our *confrères* to carefully re-examine the assertions of the English author.

In this case, and it is this which makes the therapeutic action of the protoxide of nitrogen seem quite rational, it is probable that a portion of this gas is decomposed, liberating oxygen, which acts as we have shown, and to which the curative effect is principally due,—and nitrogen, which is probably eliminated through the respiratory channels. It is to the part not decom-

posed that are due the phenomena of nervous excitation, and sometimes of anæsthesia, to which we have referred.

We will conclude by mentioning that the protoxide of nitrogen has been used in the treatment of epilepsy, and with some success, it appears, according to the paper read in April or May, 1865, at the Academy of Medicine, by M. Chapelle (d'Angoulême).

IV. HYDROGEN.

For a long time known under the name of *inflammable air*, hydrogen has, from the earliest history of pneumatic chemistry, attracted the attention of the scientists. Priestley caused small animals to breathe it, and saw them succumb at the end of a few minutes. He ascertained in this way that this gas destroys life as quickly as carbonic acid. Scheele, on his part, made physiological experiments with hydrogen, and, the better to judge of the respirability of this inflammable air, he undertook to inhale it. He filled a large bladder with it, and was astonished to find that he could breathe it without inconvenience. L'abbe Fontana, in view of the results obtained by Priestley and Scheele, which seemed in themselves to be contradictory, undertook a series of new experiments in connection with it, which he made the subject of a memoir addressed to the Royal Society of London.*

It resulted from Fontana's experiments that animals with an active respiration, like birds, die in this gas in a very few minutes, but without convulsions. Having afterward repeated Scheele's experiments on himself, by the aid of a bladder containing eighty cubic inches of hydrogen, he discovered that by breathing *into* the bladder, that is to say, by inspiring the gas contained in the bag and returning to the same the products of respiration, he could really breathe this inflammable air without inconvenience, and at the end of eleven inspirations it was so little changed by the process that it would still burn like pure hydrogen. Fontana even declared that this gas, inhaled in this manner, was more agreeable to breathe than atmospheric air. He felt at once light. His chest expanded with greater freedom, as in the mountains. He had never, he declared, experienced similar sensations, not even when breathing oxygen. Encouraged by his first trials, he desired to vary the mode of experi-

* Philosophical Transactions, abridged edition, p. 526, 1779.

mentation. He prepared a large quantity of hydrogen, with which he filled a receiver, over water, and began to inhale the gas anew, but without causing the products of respiration to be returned to the receiver. He was not able to inhale beyond the third inspiration; in fact, after the second he already experienced serious oppression.

Chaussier, by experiments on animals, determined that the respiration of hydrogen causes the blood and, in fact, all parts of the body to assume a bluish tint (cyanosis). Regnault and Rieset caused animals to breathe an atmosphere very rich in hydrogen, and announced the following phenomena:—

"The respiration of animals in an atmosphere in which hydrogen replaces nitrogen is performed exactly as if in normal atmospheric air, *except that the absorption of oxygen appears to be greater.* This probably results from the fact that the animal is compelled to respire more abundantly *to restore the excessive loss of animal heat consequent upon the contact of hydrogen, of which the refrigerant action is much greater than that of nitrogen.*"

At the end of the experiment nearly the whole of the hydrogen which had been introduced into the bell was still found there, the small proportion which disappeared having probably replaced nitrogen within the body of the animal. This result indicates an increased apparent exhalation of nitrogen, and shows a corresponding diminution of exhaled hydrogen.

Does this lowering of the temperature of animal bodies in hydrogen gas argue a special action of this gas upon the organism? We are very willing to believe it does, and perhaps there is a close relation between this phenomenon, observed in the case of animals, and the tendency to sleep which the respiration of this gas produces in men, as has been observed by several scientists. Berzelius cites an experiment, made at Stockholm by Charles de Wetterstedt, upon a consumptive young girl, in which sleep followed the use of the gas. The patient having respired a mixture of four parts hydrogen and one part oxygen for a quarter of an hour a quiet sleep followed. although she was suffering from habitual insomnia. Every time the experiment was repeated the same effect was observed.

Again, Allen and Pepys had seen guinea-pigs quickly fall asleep from inhaling a mixture of common air and hydrogen.

Injected into the cellular tissue or into the peritoneum,

hydrogen has invariably manifested special properties which deserve to attract the attention of physiologists.

Absorption of Injected Hydrogen.—In a general way hydrogen tends to rapidly disappear from the organism, after having been introduced into it. The disappearance has been sometimes so rapid that in one case an injection made into the empty peritoneum gave no traces of the gas after two hours. In all the other cases after a similar interval we have always found appreciable quantities of it. After twenty-four hours, if we except a single experiment in cellular tissue during digestion, it has been impossible for us to detect the presence of hydrogen.

"There is a phenomenon which we ought not to pass in silence, and which is explained by the exhalation of nitrogen; it is the volume [or bulk] which the animal maintains for several days after the injection. In reality, notwithstanding the disappearance of the injected gas, the animal does not at once lose the increased size which the injection had induced, so that fifteen days after an injection of hydrogen into the cellular tissue of a rabbit there was still found a considerable quantity of a mixture which in composition closely resembled atmospheric air. The presence of this mixture occasioned no derangement of the functions, and of the circumference of the animal [produced by the injection] we could readily assure ourselves that it slowly diminished from day to day, and that only after several months the animal finally resumed its normal size.

"A remarkable fact in connection with this gas is its great solubility in the blood. Water dissolves but fifteen volumes of hydrogen, while it dissolves twenty-five volumes of nitrogen. In the peritoneum and in the cellular tissues these gases are soluble in an inverse ratio to their solubility in water. From analogy nitrogen should disappear in the tissues much more rapidly than hydrogen, but, on the contrary, it is absorbed with remarkable slowness.

"This anomaly is, however, only apparent, since, according to the laws of gaseous diffusion, hydrogen should present a strong tendency to diffuse itself in the atmosphere, which contains none of it; whereas nitrogen, by reason of the volume it occupies in atmospheric air, ought to readily mingle in large proportions with hydrogen. On the contrary, when hydrogen has been absorbed and exhaled [into a receiver?] nitrogen will no longer be absorbed except in direct ratio to the difference of

the proportions which exist in the air and in the mixture resulting from the injection made."*

But let us study what has been the action of hydrogen upon the reparation of tendons in subcutaneous tenotomies.

"Our experiments relative to the action of hydrogen upon subcutaneous tenotomies coincide to demonstrate that of all the gases we have tried hydrogen exerts the most unfavorable action upon subcutaneous lesions.

"Sometimes, in case of oxygen, we have, after five days, found evidences of feeble organization in the lymph exuded between the two ends of the tendons, while with hydrogen this result is usually entirely wanting. In the latter case, in the focus of the section, there is found a little diffluent blood, the tissues are infiltrated with serum, the veins have become turgescent, and if examined later on these changes are found to persist.

"We have many times verified these results of our experiments, and we have invariably found that hydrogen had arrested or suppressed the work of reparation, toward which there is a natural tendency in all subcutaneous lesions. In these experiments, still more than in those with oxygen, we think that the rapidity with which hydrogen is absorbed and replaced by a volume of nitrogen nearly equal to its own, as the analysis given in our first essay demonstrates, must play an important rôle in the production of those permanent congestions which subcutaneous lesions always show when placed in contact with hydrogen.

"There is, however, no way to cause any toxic or even chemic action on the part of hydrogen, which strongly resists direct combinations except when in a nascent condition, as is well known. Moreover, Regnault and Rieset have proved, by experiments upon animals, that *we may substitute hydrogen for nitrogen in the atmosphere without the least inconvenience to the animal breathing it, even when the experiment is protracted to twenty-four hours.* But in these experiments, no autopsies of the animals experimented on having been made, it is not known whether, as in our experiments, any increased dilatation of the capillaries of the pulmonary arteries had occurred."†

It appears, then, that hydrogen exerts a very injurious influence upon the reparative process of subcutaneous lesions,

* Demarquay and Leconte, *loc. cit.*, pp. 38, 39.
† *Loc. cit.*, pp. 60, 61.

which it often renders impossible in consequence of the phenomena of the special congestion induced by it. The action of this gas is evident from its first application, and the turgescence it produces in the veins, which are all gorged with black blood, increases with each subsequent injection.

This subject, it may well be thought, is yet only outlined. Perhaps new investigations will develop other special properties of hydrogen, or, perhaps, by confirming ours, put them in the way of being utilized in the art of healing.

As we have already stated, inhalations of hydrogen have been tried in chronic diseases of the chest. Here, again, it is Beddoes who has investigated the subject of its use, and it is from this author that we shall quote the greater part of that which we have yet to say upon hydrogen.

After having cited from Goodwin's book ("The Connection of Life with Respiration"), a passage in which are enumerated the physiological phenomena of death by submersion, Beddoes says that the effects obtained by respiration of hydrogen are entirely analogous, as far, he adds, as circumstances permit of comparison. He has corroborated them in case of a large number of persons in good health, curious to see for how long a time they could breathe this gas. The frequency and smallness of the pulse, the cyanosing of the lips and skin, have invariably been observed at the end of a minute or a minute and a half, in addition to which there is vertigo and disturbances of vision; and, in case of animals, the cornea recedes and becomes flaccid. Some individuals experience also a certain degree of insensibility, accompanied by very agreeable sensations. A patient suffering from phthisis, who was under my care, very much liked to inhale this gas, and, in spite of my proscription of it, he acquired the habit of inhaling about a cubic foot at a time. This quantity was sufficient to pleasantly quiet his nervous system. Sometimes it induced partial asphyxiation.

Beddoes had thought that an atmosphere poorer in oxygen than common air would act as a narcotic. His induction was confirmed by experiment.

A consumptive, who for many months had been obliged to take opium regularly every evening in order to sleep, abstained from this drug for one day and inhaled hydrogen. His sleep was much more profound and restful than usual, and, what seemed to fully prove that this influence was due to hydrogen, was that

his servant, who attempted to awaken him, was astonished to find himself experiencing an irresistible sense of sleepiness. This was, in reality, caused by the room being saturated with hydrogen. We have noted, furthermore, in one of Beddoes' reported cases, that a patient suffering from insomnia was treated by inhalation of hydrogen, with equally favorable results. He also believed it would prove beneficial in cases of bronchial catarrh in the acute stage, and actually had good results in a case of acute inflammation of the lungs, using seven parts common air with one part hydrogen. The fever abated, and the severe pains of the patient were decidedly relieved. Another case, which had been ushered in by a chill, was quickly relieved by a similar mixture. In still another case, of acute pulmonary catarrh, diluted hydrogen did not sensibly relieve, but breathing the pure gas caused prompt cessation of cough and subsidence of fever. The subject of this observation, Thomas Rolph, who had previously suffered from similar attacks, and consequently had been enabled to study the comparative efficacy of various remedies in his own personal experience, declared that with hydrogen he had in twelve hours obtained as much relief, and had made as much progress toward recovery, as in a week with the aid of all other therapeutic agents.

Dr. J. Alderson reported to Beddoes a case of phthisis in which hydrogen exercised a most salutary influence. Unfortunately, too few details are given by which to judge of its value.

Burdin, it appears, also treated with success a certain number of cases of pulmonary phthisis by the use of hydrogen. Here, again, details are so meagre that we are compelled to accept his statements with a degree of reserve.*

*Personally, I have not made any extensive experiments with hydrogen gas: nor do I anticipate any very valuable results from its separate use. But the admixture of hydrogen with oxygen promises well, with reference to certain pathological conditions; and the use of this mixture deserves thorough investigation.—Trans.

CHAPTER VI.

TRANSLATOR'S NOTES, COMMENTS, AND ADDITIONS.

I. CORROBORATIVE EXPERIENCES OF RECENT OBSERVERS.

KELLOGG* reports the administration of oxygen *per rectum*, in lithiasis, with very promising results. His theory is as follows:—

Since not more than 25 per cent. of the oxygen inhaled is absorbed, while all that introduced by enema is appropriated by the system, the latter method of exhibiting the remedy is both more exact and more economical than that by inhalation. If oxygen is to be introduced into the system for the purpose of promoting oxidation processes, through which both alimentary materials and effete matters are acted upon, the former by being prepared for assimilation and the latter for elimination, especially such as are acted upon by the liver and pancreas, oxygen enemata constitute the readiest means by which the gas can be directly applied where most needed, and where it will be most promptly and fully absorbed. On the contrary, oxygen received through the respiratory organs must traverse the entire arterial system before it reaches special organs, and hence the liver and other abdominal organs will receive but a small proportion of the total quantity absorbed.

Digestion is essentially a process of hydration and oxidation; therefore, it is rational to assume that the introduction of oxygen directly into the portal circulation by means of enemata will directly and promptly promote digestion. As a test, Dr. Kellogg exposed the portal and mesenteric veins of a guinea-pig, after which he injected oxygen *per rectum*. In less than one minute after the injection the venous blood of the exposed veins assumed a bright-red color, thus proving the direct absorption of oxygen.

As a clinical test, he reports the case of a man of twenty-eight who was passing large quantities of uric acid, although restricted to a non-nitrogenous diet and drinking from three to

* Therapeutic Gazette, September, 1887.

five pints of hot water *per diem.* His skin was very muddy, sclerotic dingy, tongue heavily coated, and he complained of a constant and very annoying brassy taste in the mouth. There was also a distressing and persistent headache; in short, all the symptoms of mild uric acid poisoning. Two litres of oxygen were introduced, per enema, daily at 10 A.M. Within three days the excess of uric acid entirely disappeared from the urine, reappearing twice afterward, in small quantity, when the injections had been temporarily omitted. The brassy taste and cephalalgia both promptly disappeared.

The apparatus required for administering oxygen enemata is not necessarily complicated or extensive. A small gasometer for storing the gas, a couple of one-gallon wash-bottles, a large glass syringe for the emulsion, and a good rubber-bulb syringe for manipulating the gas, will answer. It is, however, better to adapt the wash-bottles so that hydrostatic pressure, rather than a syringe, may be utilized to inject the gas.

Humphrey* carries this idea still further. He says, in substance, that in cases of extreme debility of the stomach, liver, and pancreas, in which fatty matters can be neither emulsified nor assimilated, and in which the latter give rise to disgust and loathing, it becomes necessary to use such foods in some other way. He has tried fatty inunction, has introduced fatty foods *per vaginam*, and has resorted to the late Dr. Fothergill's method of "body-guarding" emulsified oil through the stomach, by means of soda bicarbonate; but in every case has met with disappointment. Too often, in such cases, the skin is dead as parchment, the vagina lifeless; besides, male patients have no vagina,—a fact sometimes overlooked!—and body-guarding emulsions through the stomach is necessarily a failure, where the disgusted nose and palate turn up or retch at each dose. All these efforts fail because they do not accomplish the purpose aimed at, —absorption and oxidation among the tissues,—for carbon in the human system, as elsewhere in nature, is converted into potential energy only when it meets with oxygen; and as these are the great force-producing elements of life, by furnishing these to the victim of wasting disease the flagging energies of the body can be revived until it can assimilate other foods. To do this we must utilize the shortest and most accessible route to the blood, and one which calls for the smallest modicum of vegeta-

* Medical Age, April, 1888, and Medical Record, November 10, 1888.

tive nerve force in attaining that end. He has found the lower bowel, with its extensive secreting surface, to be the road to success; its lymphatics as ready to absorb digested oil and its portal venules as ready to appropriate oxygen gas as similar vessels in the upper intestine. Albuminoids must be rejected as completely as possible, until the extreme debility of the liver has been overcome, as all digested peptones must pass that organ before they are finally metabolized; and in its debilitated condition it is powerless to split up such materials, converting them into water, carbonic acid, and urea, but, instead, permits them to form compounds of less complex nature,—bile acids, uric acid, etc. Thus, in our effort to feed our patient, we poison him instead.

Filling the alimentary canal with food is not always feeding the body; indeed, so far as immediate benefit is concerned, the food might as well be held in the hand as in the stomach, for it is only after digested principles have passed the epithelial frontier of the intestine that they become food in the true sense of the word.

In every case of consumption and other forms of wasting disease there is present from the first inception of the malady a marked inability to appropriate a normal quantity of oxygen by respiration. This may be owing to structural defects, confinement in-doors, nervous debility, or catarrhal disease of the air-passages. Let the cause be what it may, so soon as a normal quantity of oxygen fails to reach the blood and tissues, the digestive and assimilative powers fail, followed by impaired circulation of the blood and by mal-nutrition. The earliest defect in digestion is in the direction of fatty matters, for the reason that there is not present a sufficient quantity of oxygen to utilize these foods. Every one hundred parts of fat requires two hundred and ninety-five parts of oxygen for its perfect transformation; and failure to get oxygen means want of power to digest fatty foods, consequently there is a steady waste of tissues, with all that this implies. This is true not only of carbonaceous foods, but of all foods, as the quantity of oxygen present determines the capacity to digest any and every kind of food known; and the "stuffing plan" of feeding the sick beyond their power to oxidize, is a slow but certain method of poisoning them. Alimentary substance is food when the forces stored therein are given to the body by oxidation, and not otherwise.

Dr. Humphrey does not advise a prolonged resort to oxygen by enemata. He asserts that this is not necessary, but is only intended to temporarily relieve the digestive organs of their chief burden, after which they resume their wonted action and efficiency. Using his own language with regard to this treatment: "It does its work promptly and satisfactorily, restoring appetite and digestion in every case in which I have thus far submitted it."

He administers this treatment as follows:—

Freshly evolved oxygen is stored in zinc or galvanized iron reservoirs [gasometers] over water, and is drawn off into rubber bags as wanted. A bag of gas is connected by an injector—a common bulb-syringe answering—with an ordinary wash-bottle two-thirds full of any preferred solution—caustic soda or potash, "milk-of-lime," nitrate of silver, or ferrous sulphate. To the outlet tube of the wash-bottle is attached a suitable rubber tube and the vaginal pipe of a syringe. [A long, flexible catheter, of good calibre, is much preferable.—W.] Every implement is to be kept scrupulously clean.

The carbon element [hydrocarbon] is selected from any of the standard emulsions [of cod-liver oil], and two to four ounces introduced by means of a suitable glass syringe with a long, smooth nozzle, the patient lying on his back, with limbs flexed and nates brought well forward over the edge of the operating chair. The patient is enjoined to make voluntary effort to retain the emulsion by contracting the sphincter, and is allowed to rest for thirty minutes. The nozzle of the syringe or tube should be introduced far enough to pass the internal sphincter, and the emulsion is to be very slowly injected.

After a half-hour interval the tube connected with the wash-bottle and gas-bag is to be carefully inserted, the bulb having been first compressed a few times to expel all the contained air from the apparatus, and from one to six quarts of the gas is slowly injected. No fixed rule can be given as to quantity, as this must be adapted to each individual case. In no case is the injection to be continued until there is produced a sense of serious distress.

The bowel should be previously emptied by a free enema, and the injection is to be given at an interval of three hours subsequent to the last meal. [When a catarrhal condition of the lower bowel exists, the preliminary injection is much im-

proved by the addition of borax and a little glycerin. The following formula is a good one:—

℞ Aquæ (temp. 90° to 100° F.), ... ℥xvj.
Sodii biborat., ... ʒii–℥ss.
Glycerinæ, ... ℥ss.
M. Ft. sol.

Or common salt may be added to water until its specific gravity equals that of the mucous secretions. Plain water is apt to cause a feeling of uneasiness in the bowel.—W.]

As soon as possible the patient is encouraged to partake of light hydrocarbonaceous food, followed as soon as admissible by some egg-albumen, chicken, fish, etc. Meanwhile he is placed on inhalations of diluted oxygen, one part oxygen to four of pure air. Dr. H. advises that the inhaling bottle shall be half-filled with oil of turpentine, which he thinks adds ozone to the oxygen. [His pointed caution as to the danger of giving this ozonized (?) oxygen in certain conditions leads to the inference that the "annoying irritation" to which he refers does not result from possible ozone, but from acrid volatile elements extracted from the turpentine. Furthermore, the "ozone" derived from the terebinthinates has been shown to be peroxide of hydrogen.—W.]

Used in this manner, the first effect of the gas is that of a sedative; the pulse becomes slower and fuller, followed in an hour or so, not by excitement, but by a sense of well-being,—a feeling of increased strength, and a desire to get about.

Valenzuela,* starting from Paul Bert's experiments, demonstrating the destructive action of oxygen at high tension or pressure on micro-organic life, has recently conducted a series of interesting experiments to determine the effects of an atmosphere of pure oxygen, externally applied, in the febrile state. The temperature of healthy rabbits, subjected for one hour to immersion in oxygen at seven hundred and sixty† to fifteen hundred and twenty millimetres pressure, underwent a diminution amounting, in one instance, to 11° F. Rabbits inoculated with septic matter (by subcutaneous injection of putrid fluids) followed by marked pyrexia, were relieved, and the temperature brought back to normal, by immersion for an hour or two in an oxygen bath. Two rabbits, similarly inoculated, one left to its

* British Medical Journal, October, 1887.
† The normal barometric pressure at the sea-level, *i.e.*, one atmosphere.—W.

fate and the other subjected twice, at a moderate interval, to the oxygen bath, the latter survived and recovered, while the former succumbed to the poison, at the end of three days.

Two cases of acute pneumonia in hospital patients, treated with repeated immersions in oxygen at nine hundred and sixty millimetres pressure, experienced the greatest relief, and made early and favorable recovery. In a case of phthisis with a temperature of 103.6° F., a single immersion brought the temperature down to 101.3°. The next evening the temperature, having risen as usual, was promptly reduced by a second bath of oxygen. The following day no rise occurred. A third bath was given after two days, and from that time the pyrexia was either entirely wanting or of slight character.

A slight hæmoptysis followed the second bath [attributable, no doubt, to accidental causes, or, possibly, to the *pressure* under which the bath was given—W.], and this symptom was observed in a second case. The effects of the oxygen baths on the febrile state were in every instance prompt and decided. [In cases of septic poisoning, pyæmia, etc., oxygen baths will unquestionably prove of immense advantage. It is a promising field.—W.]

Wilson* sums up the results of his experiments with oxygen as follows:—

Oxygen will be found of service in the following classes of cases: First, those in which, from some obstruction in the air-passages, an insufficient supply of oxygen is allowed to enter the lungs, as in croup, constriction of the larynx or trachea, asthma, accumulation of mucus in the trachea or bronchi during coma or severe bronchitis. Second, where the lung is consolidated, either by pneumonia or tubercular deposit, or in a state of atelectasis, or compressed by pleuritic accumulation, so that only a portion of the lung is pervious to air. Third, cases of blood-poisoning, as by opium, chloroform, uræmia, etc. Fourth, cases of anæmia, as auxiliary to appropriate internal medication. Fifth, cases where it is desired to stimulate the capillary circulation, whether of the skin, as in certain skin diseases and indolent ulcers, or of the intestines when ulcerated, as in dysentery and typhoid fever.

Following Neudorfer's theoretical suggestion, Kreutzmann †

* Southwestern Medical Gazette, September, 1887.
† Pacific Medical and Surgical Journal, August, 1887.

has used oxygen in conjunction with chloroform for producing anæsthesia, and reports twenty-five patients operated upon with the most flattering success. He finds that a certain proportion of oxygen mixed with the vapor of chloroform, renders the production of either partial or profound anæsthesia both rapid and pleasant. For minor operations the obtunding of all sensibility was perfect, even when but a few inspirations of the mixture had been taken, and the reflexes were not interfered with. Prompt recovery from the anæsthetic, and absence of all the usual concomitants,—headache, nausea, vomiting, and malaise,—were marked results. The quantity of anæsthetic required was astonishingly small.

Dr. Cuneò, Physician-in-Chief to the French Navy, claims to have saved six patients in the later and usually fatal stage of cholera, by forcing pure oxygen into the lungs through the aid of a mask and tube, the latter introduced into the nares.

Kirnberger* reports a case of leuchæmia in which, after the failure of arsenical treatment, inhalations of oxygen produced a rapid increase of strength with diminution of the swelling of the spleen, the red globules regaining their normal proportion. After a few months a relapse took place, but although the red corpuscles were diminished the white were not increased —a pseudo-leuchæmia. Finally, arsenic having failed again, the oxygen inhalations were resumed, and resulted in a definite cure.

Troncin† has used oxygen inhalations in Asiatic cholera, and has noted a marked and constant betterment of the general state of the pulse.

Dr. Loyssel has experimented with pure oxygen, and from it has obtained very good results. He concludes:—

1st. That in certain poisonings, such as those by chloroform, ether, opium, sulphuretted hydrogen, carbon dioxide, cyanhydric acid, oxygen constitutes the only means of recalling the patient to life when all else has failed.

2d. That its presence in the operating-room is certain protection against fatal accidents from the use of anæsthetics.

3d. That it succeeds equally well in asphyxia caused by strangulation, by immersion, by toxic gases, etc., as well as with the newborn, in condition of apparent death.

* Union Méd., Paris.

† La Thérapeutique Méd. et Chirurg., 1887.

4th. Life can almost with certainty be maintained in all cases where respiration has not entirely ceased, even if there are long intervals between the inspiratory efforts.

5th. If the respiratory and circulatory functions have been completely arrested for a short time, they may be re-established by means of oxygen, which it is necessary to administer with perseverance, even when it is believed that all efforts will be useless. There are reported many cases of drowned persons, and of children apparently dead, who have been saved, thanks to persistence in administering oxygen.

6th. Oxygen may be inhaled in notable quantity without the least danger.

Holstein affirms that oxygen diminishes or hinders in marked manner the exaggeration of the reflexes.

Favr* has published two cases of puerperal eclampsia, where oxygen has been inhaled with complete success.

Dr. Abrahams reports as follows:—

A young man, attached to the laboratory of the New York Medical College, became asphyxiated from the inhalation of the vapor of chloroform; and so far had its effects been carried that he became pulseless, and all hopes of his resuscitation abandoned; and as all the usually recommended remedies had been tried without success, nothing but the death of the young man was looked for, when I proposed, as a *dernier ressort*, the application of pure oxygen gas as the only chance by which resuscitation could be brought about; but at the time the proposal met with opposition from the medical men present, who were anxiously watching what seemed to be the expiring efforts of the poor boy, expecting each moment to be his last. Having, however, consented, the gas had not been more than a few seconds applied to his nostrils when he who was apparently beyond the help of human skill, and absolutely *in articulo mortis*, arose and placed himself upon a chair, proving most conclusively how correct I was in proposing the application of oxygen gas as a remedy against the deleterious effects of chloroform as an anæsthetic.

Dr. Const. Paul† reports a case of opium poisoning in which the gas was successfully used after atropia had failed, and when the patient appeared to be dying; and another in which it was successfully employed in narcosis from charcoal gas.

* Vratch, No. 13, 1885; *loc. cit.*

† Ranking's Abstract, xlviii.

Sieveking* reports two cases of restoration by oxygen in poisoning by carbon.

Dr. Smith (A. H.) says it is his firm conviction that oxygen will do in croup all that can be done by tracheotomy, although neither the one nor the other is competent to undo the mischief wrought by severe and protracted dyspnœa.

Ducroy asserts that pure oxygen, contrary to the general belief, can be inhaled for several hours without being detrimental to health; its action is antagonistic to that of chloroform; it is a powerful remedy for the disagreeable accidents arising from chloroform and other anæsthetics, and in asphyxia from poisonous gases—as, for instance, from carbonic acid—it exercises, likewise, a beneficial influence . . . .

Every patient awaking from a chloroform narcosis should inhale oxygen, in order to rid himself of headache and other inconveniences following the administration of that anæsthetic.

Jaccoud's treatment for chronic Bright's disease consists in limiting the patient to a very simple dietary, inhalations of pure oxygen to the extent of ten litres three times daily, to which he adds, as a further stimulant to the accelerated processes of metabolism and tissue metamorphosis, the systematic application of douches and vigorous massage. The results are always favorable, mitigating the severity of the malady in such cases as are found to be incurable.

Hayem,† Professor of Therapeutics and Materia Medica in the Medical Faculty of Paris, reports the results of daily inhalations of oxygen by persons in health as follows: "It produces a very decided stimulation of the functions of nutrition. It augments the appetite, perceptibly elevates the temperature, accelerates the circulation, and increases the body-weight. It favors the evolution of hæmatoblast and of red globules, increasing the proportion of the latter in hæmoglobin as much as 5 to 10 per cent."

He also confirms the statement of Beddoes that the immediate operation of oxygen is doubtless to render the action of the heart and arteries stronger, the remoter effects being an increase of the red color of the blood when pale and a heightening of the complexion.

* The Lancet, 1869.

† Paper read before the French Academy in 1881; quoted in London Practitioner, October, 1888.

Referring to chlorosis, Professor Hayem asserts that oxygen renders unquestionable service to chlorotics afflicted with digestive troubles. It revives the appetite, checks vomiting when present, restores the function of assimilation, and increases the body-weight. He found that while the red corpuscles were greatly increased in number, their pathological characters were constantly repeated, but that subseauently, on having recourse

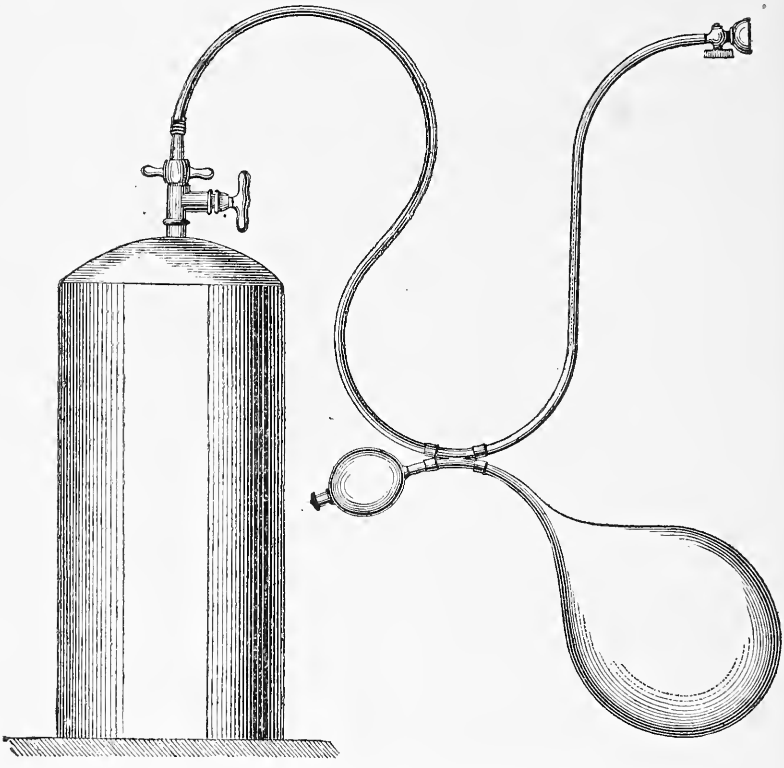


FIG. 10.—BRIN BROTHERS' INHALER, AS USED BY PROFESSOR HAYEM (*London Practitioner.*)

to chalybeates, the red corpuscles promptly acquired normal characteristics, and the cure was rendered complete and permanent. He obtained complete success with oxygen and iron, administered simultaneously, in cases in which iron alone was of little or no service. He also found oxygen of the greatest value in the incorrigible vomiting of pregnancy and in the vomiting of uræmia.

Winsor,* speaking of heart foods, advances the following timely hints:—

Respiration is essentially a nutritive function, and the constant waste and repair of the cell-elements of the body as much require the oxygen of the air for their transmutation as do the hydrocarbons, albuminoids, and fats of the blood. . . . . As a rule, the lungs are not considered as an organ of nutrition, but a critical examination of the function of respiration will leave no doubt on this point. The *besoin de respirer* does not lie in the lungs themselves, but in the want experienced by the system at large.

Hence the dyspnœa in heart disease, even when the lungs are performing well and the circulation is fairly good. The non-oxygenation of the tissue-cells is the cause of the imperative demand for air. . . . . The action of oxygen is one of nutrition, and is therefore of paramount importance. . . .

It is a fact that the tissues will absorb oxygen and give off carbonic acid without the intervention of the circulation; hence, we must infer that the appropriation of oxygen is due to the demand of the cells for this essential element.

Therefore, a rational method of diet in cardiac diseases must include not only tissue foods and fuel foods, but also an increased supply of oxygen, without which the former may prove valueless.

An increased supply of oxygen rather than a stimulated circulation; saturation of the blood with this element rather than an increased supply of poorly aërated blood, is the desideratum in prescribing a diet for heart disease.

[In such cases of mitral insufficiency, cardiac dilatation, and fatty degeneration of the heart-walls as have fallen to my lot during some years past, no remedy has given such *permanent* results as oxygen inhalations. It has enabled a majority to recover a fair degree of robustness, and when promptly exhibited has seldom failed to *relieve* the most alarming symptoms in even incurable cases. I have therefore learned to rely on it, not only as an invaluable adjunct, but as the safest and best of heart tonics. Referring to my repeated contradiction of prevailing impressions that an excessive or prolonged use of oxygen may induce inflammatory action in the respiratory organs or elsewhere, I would cite a case still under observation in which

* Dietetic Gazette, 1888.

oxygen has been inhaled twice daily with rare omissions, and without the slightest indication of harm, for a period of more than fourteen months; the occasion for its use being cardiac dilatation with mitral insufficiency and regurgitation, following severe and repeated attacks of inflammatory rheumatism.—W.]

Professor Thompson* (W. G.), at the Loomis Laboratory, recently conducted a series of ingenious and interesting experiments with various animals, confining them in pure oxygen and also in a mixture of oxygen and nitrogen monoxide, at all degrees of tension, from one to ten atmospheres. He proved that asphyxiated animals can be resuscitated by immersing them in oxygen at high tension—five to seven atmospheres—after they are absolutely beyond help from artificial respiration or stimulus of any kind. He also found that animals confined in compressed oxygen for a number of hours were finally attacked by convulsions, the same as those caused by close confinement in compressed air, except that in the latter case the convulsions occurred much earlier, counting from the moment of immersion. He is inclined to attribute these convulsions to the carbonic acid and ptomaines emitted by the animal itself while in confinement, and not wholly to the effects of either the oxygen or to compression. Professor Thompson fully confirmed the former experiments to the effect that under various conditions, as tension, etc., a quantity of oxygen is absorbed into the system somewhat in excess of that realized from normal atmospheric air. Animals can thus be fortified against asphyxiating gases and other toxic influences, and by means of compressed oxygen can be resuscitated after having been practically dead for some minutes from asphyxiation.

Professor Thompson and others who took part in the discussion which followed his paper commended the use of oxygen in a large number of chronic conditions, including the indigestions, anæmia, chlorosis, incipient phthisis, gout, rheumatism, etc., as well as in nearly all the emergency cases, such as croup, diphtheria, dyspnœa from any cause, heart failure, opium and chloroform narcosis, in which it is the only reliable means of saving life. During the discussion Dr. Smith (A. H.) asserted that his experiences with oxygen, reported twenty years ago, have been substantially confirmed by his more recent experience.

Dr. Robinson (Beverley), responding to the assertion that thorough and systematic inhalation of pure air affords all the

* N. Y. Medical Record, July 6, 1889.

oxygen that can be utilized in the animal economy, showed that such an argument against the therapeutie use of oxygen is foolish, because of the practical fact that not one person in a hundred is so situated as to command free access to pure air, or to inhale it in a thorough and systematic manner, even were pure air everywhere available. Dr. Robinson has found great benefit from the use of oxygen in a large class of both acute and chronic diseases.

Dr. Radcliffe has used oxygen in chronic and intractable cases of indigestion, and in the general debility resulting from chronic uterine and ovarian disease, with uniformly satisfactory results. He has also realized decided amelioration in carcinoma and degenerative ulceration of the uterus and appendages, by combining the constitutional use (inhalations) with local application of the gas (oxygen douches). He has applied a spray or douche of oxygen mixed with various proportions of nitrogen monoxide, directly to the parts, with the happy result of allaying the patient's sufferings and overcoming the intense and almost intolerable fœtor usually present in these cases.

Speaking of the therapeutic action of oxygen in a general way, Dr. Radcliffe makes the apt remark that it at all times tends to restore to normal conditions; *i.e.*, if the patient be obese it will reduce flesh; if too thin it will foster an increase of weight; if oversensitive, the nerves are both soothed and "toned up;" if lethargic, the system is aroused and stimulated, etc.

Ransome* records his experience in the treatment of pulmonary phthisis by inhalations of oxygen, and the results are interesting:—

Taking thirteen cases at all stages, nearly all of whom were under observation for one year and some for two years, only two distinctly lost rather than gained, and one of these died of laryngeal phthisis. The points of improvement consisted in the continuous absence of fever, absence of night-sweats, diminution of amount of expectoration, decrease in degree of anorexia, and increase in sleeping power, followed by a gain in flesh. The oxygen did not seem to harm the bacilli by any direct influence, but simply by increasing the vitality of the patient to such a degree that the lungs proved a less fruitful ground for the growth of micro-organisms. In the experiments of Ransome the gas was inhaled, and the *séances* occurred twice or

* Medical Chronicle, May, 1889.

thrice a day. How much of the gas was taken we do not know, as Ransome says two cylinders, but does not state their capacity. This is a point, however, which must be decided for each case, and the practitioner can so readily obtain compressed oxygen in cylinders, at a moderate cost [or better, perhaps, prepared on the spot—W.], that it should be tried by many of us who are at a loss for something to do for a class of cases constantly begging for the help which we cannot give.

II. PERSONAL OPINIONS AND EXPERIENCES.

To the careful and candid reader of this work it must be apparent that Demarquay was both an earnest and, in the main, an astute observer. While his favorite field of study and practice was that of surgery, he was at the same time eminent as a physician; for one may be a good physician without being more than an ordinary or indifferent surgeon, but no man can be deservedly eminent as a surgeon without first becoming a thorough physician.

Sometimes tinged with enthusiasm—which is frequently excusable—his opinions are candid, and his cases are reported with an evident fidelity to truth not always found in the advocates of new or unpopular therapeutic methods. His chemical manipulations can now be much improved upon. In fact, his one weak point was a lack of aptness in the chemical department of his investigations. He does not seem to have courted the laboratory; on the contrary, he appealed to the crucible only from necessity, shifting all possible responsibility in this direction upon his pharmacist and his pupils. It is evident that his oxygen was constantly tainted with chlorine and with vaporized but undecomposed particles of chlorate of potash. Generated rapidly, over an ordinary laboratory furnace, with no precautions as to excessive heat, and washed through a single chemical solution —"milk-of-lime"—it was not possible to avoid these and other impurities.

To this fact must be attributed his pervading belief that an excess of oxygen implied inflammation, and might even terminate in ulceration, tubercular degeneration, and gangrene. Irritation and inflammation of the respiratory tract no doubt occurred in the animals he so mercilessly sacrificed on the altar of scientific experiment. Fortunate were his human subjects if they escaped serious injury from the same source.

This idea that an excess of oxygen inevitably tends to excite inflammatory action still more or less pervades the professional mind. It is one of those scientific errors which has so long been accepted without serious question that it has assumed as much respectability as though it were a veritable scientific fact.

Burdon-Sanderson long since effectually exploded it by proving that the red globules of the blood are the principal transmitters of oxygen; that the activity of the white corpuscles is in exact proportion to the per cent. of oxygen present; and that *the primary stage of inflammation consists in a sluggish and finally immobile condition of the white corpuscles, from lack of a normal and sufficient supply of oxygen!*

When this physio-pathological bugbear concerning the inflammatory tendencies of oxygen shall have been effectually and finally laid, there will be a clearer field for physiological and therapeutic progress in connection with a study of this gas.

Practically, the danger from excessive absorption of oxygen is next to nothing, since any oversupply inhaled is, for the most part, at once expired—rejected. Here, as elsewhere in the animal economy, the law of supply and demand constantly asserts itself. The system appropriates what it needs and can absorb; the surplus is largely—perhaps not quite entirely—returned to the air. According to Richardson, the rejected portion has perhaps lost some of its magnetism or vital affinity, but otherwise it is unchanged. (See note, page 117).

The Tendency of Medical Thought.—It is beginning to be evident to even casual observers that the medical science of the future must be largely based on a more careful study of natural therapeutics. As a profession we are slowly emerging from the shadows of medical superstition. Just now the novelty-craze is in the ascendant; but everywhere the thinkers are tiring of the constant succession of dear-bought and far-fetched methods and materials, each of which has its brief hour of renown and is then cast aside by a virtual return to the older standards. Convallaria, adonidine, and strophanthus, even with the aid of sensational advertising, have failed to displace digitalis; while chloral, hypnone, and sulfonal do not seriously interfere with the steadily increasing demand for opium and its derivatives. The heyday of pharmacomania is not yet

passed, but the reaction against dispensatory routine and medical fetichism has set in. The inevitable result is but a question of time, and can be easily foretold. Routinists no longer take front rank, but must be content to become rear-guard and camp-followers in the army of medical progress.

The time has come, in the history of medicine, when every therapeutic claim, every honest endeavor to abridge or ameliorate human suffering, add comfort to the days and length to the years of human life, is accorded a respectful hearing, and is finally judged on its absolute merits. This is true, even to the impartial and unprejudiced investigation of the scores of popular isms and ephemeral pathies which every decade brings frothing to the surface.

Throughout the medical world, analysis, speculation, and research are active and eager for new light. Routine methods and antiquated theories, which have only popular prestige and venerable antiquity to sustain them, are no longer competent to satisfy thinking minds. Our foremost writers, teachers, and investigators have begun to insist on reasonable data for every assumption, They refuse longer to rest their medical faith on dogmatic assertion and time-honored tradition, insisting that medicine, mystery, and superstition, have long enough been in vogue as synonymous terms.

Heretofore the study of medicine has involved and required, chiefly, a process of memorization—cramming—and the cultivation of an aptitude for implicit belief. Now, it requires that its devotees shall investigate, criticise, and think.

The one unremitting search of the day is for a key to the true nature of disease, and for remedies which do no violence to natural laws, which do not contravene physiological action by substituting one condition for another, assuming that since it is a change it is a cure. Hence the imminent and irrepressible conflict in the medical field lies between natural, as opposed to artificial therapeutics. In these later days, every society meeting and medical congress brings to the front new knights to champion fresher ideas, and to pierce the armor of established errors.

Medical skepticism, of a rather healthy and conservative sort, is daily and yearly increasing, and standard text-books on materia medica and therapeutics are coming to be looked upon as indexed museums of medical curiosities. The list of reputed

remedies has ostensibly multiplied, but new claimants are received with incredulity, and the pharmacopœia is being so mercilessly culled of its rubbish that even well-poised medical minds begin to query how long before the whole endless category of drug-medicines, with a few rare exceptions, will be unceremoniously kicked into the sea.

The realm of the *vis medicatrix naturæ* is being found broader and more comprehensive than has yet been conceived of or admitted. On this mysterious recuperative power, with which every organized being is normally endowed, and with which all the forces of nature are inherently charged, the intelligent and conscientious physician leans with unhesitant confidence. On his thousand ever-multiplying and alluring but delusive drugs he looks with well-grounded and growing distrust; while unreasoning faith in charms, philters, and mystery—a heritage from barbaric days—no longer holds him in thrall. One by one the myths are fading from the medical skies. Every year's experience adds to the growing conviction that the remedial forces of Nature are the foundation and crown of all curative processes. All else is open to the suspicion of being patchwork and palliation.

This more and more frequent appeal to natural agencies as aids in the prevention and removal of diseased conditions bids fair to emphasize an epoch in the history of practical medicine. Nor is it by any means a limited or barren field. It includes all forms of galvanism and electricity, the various and numberless applications of the forces and influences of heat and cold, light and darkness, motion and rest, labor and recreation, nutrition and waste, aëration and ventilation, personal magnetism, passional and psychic relations, and all moral and social surroundings. It involves a study of climatic peculiarities, of habitations, dress, occupations, and of every external and internal circumstance and influence which has any natural bearing on the comfort, progress, and prospects of human existence.

Objections Answered.—Of all the agencies or forces of nature, oxygen, in its predominance as to quantity, in the illimitable range of its chemical relations and vital affinities, and in its incessant and irresistible activities, easily and irrevocably stands at the head of the list.

It is, therefore, both natural and reasonable that the therapeutic employment of oxygen gas should no longer be of ques-

tionable utility. It is gradually commanding attention in the highest professional circles, and is being recognized as a desideratum in numerous conditions which have hitherto proved tedious or wholly unmanageable; and yet a large class of physicians at the present time flippantly dispose of this question by citing the current saw about the saturation of the blood. They repeat that scientific stupidity which assumes that the free oxygen in the blood cannot be increased beyond the limited quantity which it constantly and readily receives from the ordinary atmosphere, and hence that any attempt in this direction is not only uncalled for but practically futile. Should we, for the sake of the argument, grant that this assumption is true, the objection practically falls flat. If the human race could be turned adrift in a body, and should lapse into the primitive life of nomads, it might be feasible for each individual to realize his due quantum of the vitalizing element. Unfortunately, civilization implies a sort of human hibernation, and the average modern individual is compelled to eke out his disease-pestered days on one-half this allowance, or even less. The sequences are unavoidable. Functions are imperfectly and incompletely performed; changes and metamorphic processes, though initiated, necessarily flag and result in half-formed tissue, or in products inimical to the healthy organism. Toxic, carbonaceous elements accumulate, degenerative processes are set up, and chronic disease is the inevitable result, if even malignant demonstrations do not end the disastrous history.

These are homely facts, and have no glamour of superficial laboratory erudition or bacillus-staining to give them apparent dignity. Nevertheless, they appeal to the hard, common sense of every practitioner of medicine, who realizes how helpless he is to relieve the many and multiplying forms of disease constantly presenting, and constantly being analyzed, by the aid of the scalpel and the microscope, with a minuteness of detail which is fairly bewildering,—and which are the direct or remote results of this universal, and in a large measure compulsory, oxygen famine.

The history of every novelty, innovation, or advance in the line of therapeutic measures, is marked and punctuated by a succession of vicissitudes and experiences so uniformly resembling each other in general features, that a student of medical history might forecast them in any given case, with greater

accuracy than is shown in the average predictions of the Signal Service Bureau.

First, there is the original enthusiast, who sooner or later multiplies—possibly by the process of fissiparism—into a more or less respectable corporal's guard of camp-followers, who soon succeed in earning the slangy modern title of "cranks." Goaded by opposition and unkind criticism, they take revenge by indulging in an almost vituperative overstatement of facts, and overestimate of possibilities, call down upon themselves merited ridicule and persecution, and this generally culminates in abuse and ultimate professional ostracism. This is much less true at the present day than at any former time in the history of medicine. Never was the profession so ready to greet new assumptions with respectful tolerance, and to give them ample opportunity to demonstrate their worth or worthlessness. Instance the fairly epidemic furor with which Bergeon's unnatural and irrational treatment of phthisis swept over the country. Instance, also, the stenocarpine "fake."

So each new theory, vaunted specific, and therapeutic hobby suffers its period of decadence, following a brief heyday of novel popularity, and, regardless of its merit or want of merit, falls into desuetude, if not into contempt. If its claims be based on chemistry, common sense, or clinical experience, it eventually emerges from its undeserved banishment, and is sooner or later revived, or perhaps rediscovered; after which old assumptions are revamped, fresh experiments are conducted, and, finally, some renowned clinician or acknowledged authority sets the seal of success upon it by adopting it as his own god-child. As examples of this kind, electricity, hydrotherapy, and massage may be cited.

Referring to the history of therapeutic oxygen, Fourcroy was the first genuine oxygen "crank." His epitaph should have been,—"*Behold the first victim of oxygen mania!*"

However, we must not deal harshly with his memory, since we have the satisfaction of knowing that most of his scientific vagaries were buried with him.

Beddoes was honest and earnest; but he lacked the courage of his convictions, and was hopelessly hampered by the limping chemistry of his day. Hill spoke with less reserve, but he had no audience. Birch was an enthusiast, but did not arouse much professional interest. Demarquay cleared up much that

was in doubt; but he, too, must await the slow evolution of medical thought. It remains for America to add her modicum to the gradually accumulating weight of evidence as to the therapeutic value and availability of oxygen and the other gases, properly exhibited, in suitable cases.

With those practitioners who have familiarized themselves with all the physiological tests made, within the last quarter of a century, there can remain no rational doubt but that the blood can and does, under certain conditions, appropriate more than a normal or average quantity of the vitalizing element. It is not a question as to whether, under the most favorable conditions, a normal and sufficient supply of this element is, or would be, uniformly appropriated; because "the most favorable conditions" are at the command of but a favored few of the human race.

We cannot, even with all our progress in science and the arts, any more than approximately control our surroundings. We cannot make our climates; we cannot all remove to "the best climate under the sun," if even such a Utopian climate shall ever be discovered. We cannot all choose our occupations, or make the one selected a wholly salutary one. Our habitations are anything but ideal temples for daily ovations to the goddess of health; in spite of us, our neighbors will maintain noisome encumbrances. Slow poisons float about us in the air, filter through the hydrant, or ooze into our springs and wells. The food-mongers adulterate everything; the confectioner feeds our children arsenic and aniline, and the canned-goods man corrodes us with metallic citrates, tartrates, and malates. The victims of phthisis, of scrofula, and of syphilis have been for ages propagating and distributing, right and left, their germ-breeding sputa and excreta, with little or no regard to age, sex, or personal culpability, until there is no longer any possibility of living in a sterilized or normally healthful atmosphere. Even were all these foreign sources of contamination removed, we are incessantly shedding our own vile emanations of ammoniacal odors, choke-damp and ptomaines, to poison both ourselves and our neighbors. The mythical garden of Eden, alas, bloomed only to perfect the deadly nightshade of the race!

Even admitting that the normal man is adapted to the normal atmosphere into which he was born, and that the normal atmosphere is all-sufficient for all the needs of the animal life existing in it; there is plenty of occasion for a resort to artificial

oxygen, to antagonize the thousand and one untoward influences which, despite all our best endeavors, constantly and everywhere thicken about us.

Of the process of respiration, we barely remember to have been told that when the average man takes a full inspiration he has distended his lungs with about one hundred and seventy-five cubic inches of atmospheric air, consisting of about one hundred and forty parts nitrogen and thirty-five of oxygen. Something the books add, in a dogmatic way, about chemical blood changes, the burning up of nitrogenous waste, and the conversion of hydrocarbons into heat. Thus, oxygen, that sole element in which all other elements, even diamond itself, are consumed with fervent heat, the essential principle of all life, is degraded into a mere mechanical motor—the steam-generator of the vital organism!

Looking more closely into the nature and composition of this theoretically tasteless, odorless, and impalpable fluid, it is now conceded that the oxygen of the atmosphere, its atoms pushed asunder and probably modified by the interposed nitrogen, exists in a peculiarly quiescent state; that the atmosphere at all times contains appreciable quantities of aqueous vapor, carbonic acid and ammonia, also traces of ozone and peroxide of hydrogen, the two latter being frequently confounded and mistaken one for the other.

The respiratory function, the most intensely vital and important of all the bodily functions, and the one on which hinges the performance of all the others, is but indifferently accomplished by a large majority of the race. Who breathes most, eats, digests, and assimilates most, and sleeps most soundly; conversely, who breathes least lives and enjoys least. The individual heaven bears strict relation to the size and vigor of the individual lungs; and the stethoscope is capable of supplying competent testimony as to the moral breadth and intellectual ability of every individual member of the race. *Not one in a hundred realizes a dozen thoroughly complete and physiologically ideal inspirations of absolutely pure air per annum.*

The cavillers at the idea of superoxygenation seem to have overlooked this palpable fact.

Cases Treated.—The following table of cases is selected from the writer's note-books, and from creditable reports of others, transmitted for the purpose:—

LIST OF CASES TREATED BY OXYGEN—CHIEFLY BY INHALATION.

Diseases Treated.	Number of Cases.	Treatment Inefficiently Pursued.	Cured or Fully Relieved.	Sensibly Relieved.	Little or Not at All Relieved.
Anæmia	28	9	17	7	4
Asphyxia	19	3	9	8	2
Asthma, humid and dry	34	7	21	11	2
Bright's disease	7	7	0	4	3
Bronchitis, subacute and chronic	24	3	13	8	3
Catarrh, chronic nasal	17	11	3	6	8
Catarrh, chronic gastric	21	7	11	3	7
Carbuncle	2	0	2	0	0
Chorea	7	2	5	1	1
Constipation	47	18	22	18	7
Diabetes	8	7	0	3	5
Dyspepsia (not otherwise classified)	19	3	13	3	3
Eczema, chronic	11	6	3	2	6
Epilepsy	3	1	2	1	0
Epithelioma	1	0	0	1	0
Fever, malarial	11	6	3	4	4
Glandular enlargements	7	3	4	1	2
Headache (all varieties)	31	11	16	4	11
Heart disease, valvular and degenerative	12	7	4	6	2
Insomnia	13	7	6	4	3
Locomotor ataxia	3	2	0	3	0
Menstrual irregularity	17	6	10	3	4
Narcosis (opium, chloroform, belladonna, etc.)	6	1	4	2	0
Neuralgia	13	4	6	3	4
Neurasthenia	21	7	11	4	6
Ovarian disease	7	2	4	1	2
Paralysis, partial	4	2	2	1	1
Pertussis	7	2	4	1	2
Phlebitis, crural	2	0	2	0	0
Phthisis pulmonalis	11	3	4	6	1
Pyæmia and septicæmia	9	2	5	1	3
Rheumatism, chronic articular and general	15	4	6	5	4
Sciatica	6	3	3	1	2
Syphilis, secondary	3	1	0	2	1
Totals	446	157	215	128	103

III. OTHER METHODS OF ADMINISTERING THE REMEDY.

Experience with oxygen baths has been, as yet, very limited. There are, nevertheless, many chronic cases in which these baths will prove decidedly beneficial, as well as very grateful to the patient. The requirements in the line of apparatus necessary for administering gaseous baths will probably deter a majority of practitioners from using them, but this objection is scarcely

more pertinent than when it was urged against ordinary hydrotherapy, facilities for which are now made legal requirements, in case of tenement and apartment houses, in most large cities. Besides, the question of their use having been more or less agitated, the ingenuity of manufacturers will be taxed to give us more convenient, and perhaps more economical, appliances. The writer suggests, as a happy union of the two ideas,—compressed air and oxygen baths,—that dilute oxygen baths, to be given at moderate tension, be substituted. This can be accomplished, as has been practically demonstrated, by quite simple and comparatively inexpensive appliances. A cabinet, such as that used for administering portable Turkish or vapor baths, is reinforced with an extra lining of rubber cloth, or other non-porous fabric, the joints made practically air-tight by means of strips of pure sheet-rubber or felt; a lid, provided with an opening for the head, and a rubber hood, so attached as to snugly enclose all but the face of the patient. The latter, being seated inside this cabinet, is prepared for his gaseous immersion by the same means used to induce free diaphoresis in the Turkish or vapor bath. After a brief but free stage of perspiration the heat is removed, the patient quickly rubbed dry, treated to a rapid douche, or to a shower-bath, as preferred in each particular case, and the cabinet again tightly closed; after which a stream of cool or warm oxygen is admitted through a tube inserted near the bottom of the cabinet.

The contained warm air, vapor, animal emanations (and ptomaines?) are allowed to escape through an opening at the top. As soon as a lighted match shows that oxygen has begun to escape at this opening, it is to be tightly corked or otherwise closed, and more gas forced in, under a few pounds' pressure. The patient remaining thus immersed for twenty or thirty minutes, fresh portions of gas are to be forced in, from time to time, to replace any loss by leakage of the apparatus, and to retain the desired degree of tension or pressure. This procedure will prove eligible in a variety of chronic cases, including *septicæmia*, or blood-poisoning, *rheumatism*, *phthisis*, and *chronic skin diseases* of an inveterate character. Moreover, its influence, as a general tonic, will be available in nearly all cases of general debility and wasting disease, with diminished breathing capacity, so that there is really no limit to its range of applicability.

Besides, there are very many cases in which there is general

torpor of all the functions. The bowels, kidneys, and liver do their work imperfectly. The skin, in the language of Dr. Humphrey, is "dead as parchment." The lungs are cramped and unused to free inflation, and all the emunctories tardy in performing their various offices. In such cases inhalations of oxygen relieve the symptoms very slowly, if at all, for the reason that the inhaled gas is not properly or promptly absorbed. The combined bath, which might be named the *Oriental-Oxygen Bath*, repeated once or twice per week, promises in these cases very auspicious results.

A rational and partial substitute for the gaseous submersion above described may be administered by means of sprays or douches of largely diluted hydrogen dioxide. This form of bath has not been practically tested to a sufficient extent to enable one to speak unreservedly of its effects; and, while the cost of the material required may be to some extent a bar to its popular use, there are many cases in which it would prove a valuable and easily available auxiliary to other treatment. Unexpectedly favorable results have been realized from its local application in a number of different ailments. Details need not here be given, but a few suggestions, to indicate the range of applicability of the remedy in this form, will not be out of place: *Dry eczema*, subacute and chronic; *septicæmia*, general, or with local manifestation; *urticaria* and *itching eruptions*, various as to origin and character; *furuncular eruptions*, *acne*, *tinea capitis* and *t. tonsurans*, *pruritus*, local or general, etc., etc.

When better known it may also find extensive use as a cosmetic application; for example, for removing *tan*, *sun-burn*, *freckles*, *moth patches*, etc., etc. This it will generally do in a pleasant and efficient manner. Elsewhere this interesting product of the laboratory is treated of more at length.

IV. TESTS FOR THE PURITY OF OXYGEN.

The readiest tests of the purity of a given sample of oxygen are the senses of taste and smell. To acute olfactory organs and a sensitive palate, any material taint of chlorine (the most common impurity) will be at once apparent. Absolutely pure oxygen, in its ordinary or passive condition, is tasteless and odorless; but in all nascent oxygen the trace of ozone present imparts a faint odor and slight pungency, which, to those who do not easily distinguish flavors and odors, may easily be mis-

taken for chlorine, although, after a little experience, there ought to be no confusion on this point.

A positive test consists in burning a piece of phosphorus within a bell or receiver suspended over water and filled with oxygen. If the contained oxygen is completely consumed, through the combustion of and combination with phosphorus, the bell will be completely emptied, since the phosphoric acid formed is wholly absorbed by the water. Should any other gas or gases be present, the bell will fail to be emptied by this expedient. The impurities most liable to be present are chlorine, hypochlorous acid, carbonic acid, carbonic oxide, nitrogen, and common air. The two latter are entirely negative, so far as therapeutic effect is concerned, as they merely dilute the gas to the extent of their contained volume. Gas containing appreciable quantities of either of the others is unfit for therapeutic exhibition.

V. CHEMICALS AND FORMULÆ.

To secure perfectly pure oxygen for medicinal use, it is necessary to use none but the best chemicals. The materials required are potassium chlorate and manganese dioxide. It is well to add a trace of carbonate of iron, after the suggestion of Fresenius, as a partial safeguard against the evolution of chlorine. Squibb's recrystallized chlorate, either pulverized or granulated, is unexceptionable as to quality. Of foreign brands the quality is not always reliable; in fact, there are as many qualities as there are brands, nearly all of which claim to be "pure." Some of them are practically as good as need be used, and cost a little less than Squibb's. But it is advisable to procure the best, and thus be absolutely sure as to the purity of the chemicals used.

Of manganese, the average quality offered in the market is very poor, assaying from 25 to as much as 50 per cent. of dirt and extraneous matter. It is not necessary that the manganese used be chemically pure, but it should not contain to exceed 10 per cent. of impurities. In the better and cleaner varieties, which are chiefly imported, the impurities consist principally of ferric oxide, which is a negative, and therefore harmless, ingredient.

For the preparation of nitrogen monoxide, pure ammonium nitrate is used, the granular form being preferable to that which has been fused or crystallized. A trace of ferric carbonate may

be advantageously added. Glass or porcelain-lined iron flasks are to be used in the preparation of this gas.

In conducting the process for either oxygen or nitrogen monoxide, the heat should be applied gradually and uniformly. Hurrying the process in either case injures the product, by evolving sundry by-products, and changing others. Many experimenters are quite careless in this respect.

FORMULÆ.

1. For Preparing Oxygen Material.

℞ Potassii chloratis (pulv. vel, gran.), . . .	℔s iv.
P. manganesii dioxid., ...	℔s j.
P. ferri carb. prec., ...	ʒij.—M.

Triturate the ingredients with some care until well mixed, pass once or twice through a No. 16 wire sieve, and dry in a moderately warm, open oven. Store in wood, tin, or glass containers, carefully excluded from air and moisture. One pound of this mixture will yield about twenty-eight gallons of oxygen.

2. For Preparing Nitrogen Monoxide.

℞ Ammonii nitratis (pure), ...	℔s v.
Ferri carb. prec., ...	℥j.—M.

Store in wood-, glass-, or stone- ware.

3. For Preparing Nitrogen.

The preferable process for procuring pure nitrogen, since, unlike some others, it is devoid of danger, is by the decomposition of a solution of potassium nitrite with ammonium chloride (sal. ammoniac). On boiling this solution, after the addition of the ammonium salt, nitrogen is evolved and potassium chloride remains in solution. It is well to pass the gas through an alkaline (caustic) solution, or through a weak solution of nitrate of silver.

To prepare a mixture of "two parts oxygen and one part nitrogen,"—a mixture now being paraded in the market with considerable advertising bombast,—add fourteen parts pure oxygen to ten parts common air. In other words, dilute your oxygen with common air, in the above proportion. Cost of the mixture, if prepared by yourself, one cent per gallon.

4. For Preparing Hydrogen.

Into the neck of a wide-mouth glass jar—an ordinary wash-bottle answering every purpose—insert the usual perforated rubber cork. A long tube, with the top end expanded into a funnel, is to be inserted, through one of the perforations, nearly

to the bottom of the jar, and a bent glass outlet-tube inserted into the other hole. Granulated zinc, or simply scraps of the metal in malleable form, is put into the bottle, together with a little water. Sulphuric acid is now to be slowly added through the glass funnel, the lower end of which must at all times reach below the surface of the liquid. The evolution of gas will be in proportion to the quantity of acid added, and is therefore easily regulated. It will issue from the outlet-tube, and is to be collected in the usual manner, or conducted into any convenient gas-holder.

Experimenters should bear in mind that hydrogen is the original "inflammable air," and that it may become a dangerously explosive compound by any careless admixture with common air, or with oxygen.

5. For Carbon Dioxide.

The process for evolving carbon dioxide (carbonic acid) is too common to need repetition here. This gas may also be had in all the larger cities, compressed in iron cylinders, at moderate cost.

VI. ADDITIONAL SOURCES OF OXYGEN.

(*a*) *Hydrogen Dioxide* (H_2O_2).—Another source of free oxygen which Demarquay seems not to have tested, but which is certainly a great addition to our resources, is found in hydrogen dioxide, or peroxide of hydrogen, as most writers continue to call it.

In connection with the author's comments on the surgical availability of oxygen, and since he seems not to have made any use of this oxygen-yielding compound, the writer has thought it desirable to give a succinct summary of its medical and surgical uses, and the methods of utilizing it.

Passing over the familiar facts of its discovery by Thenard in 1818, and its subsequent experimental history, of interest chiefly to chemists, it is now slowly but steadily coming into use and gaining substantial repute in the treatment of some diseased conditions, especially those of septic, zymotic, and parasitic origin, the management of which has hitherto been tedious and often unsatisfactory.

Its symbol, under the nomenclature now in vogue, but which may be further metamorphosed before the end of a decade,

is H_2O_2, instead of HO_2, as under the former system. Its preparation in a pure form is somewhat difficult, and, as a majority of the samples offered in the market are wholly unfit for use in medicine, no experimenter should be discouraged by a few preliminary failures. The process of manufacture is omitted.

It is quite commonly but erroneously called "oxygenated water," since it is not water at all, but a distinct and definite compound of oxygen and hydrogen, containing exactly twice as much oxygen as water, or sixteen parts of oxygen to one of hydrogen. In its pure state it is a syrupy liquid, colorless, transparent, and almost or quite inodorous, having a specific gravity of 1.453, and yielding four hundred and seventy-five times its own volume of oxygen. It will not freeze, is a little less volatile than water, and is somewhat unstable at ordinary temperatures. It is promptly decomposed into oxygen and water at about 100° C., sometimes with explosive violence, and at much lower temperatures by a variety of diverse substances, as gold, silver, spongy platinum, and permanganate of potassium; by blood, fibrin, albumen, and some other organic substances, none of which take any part in the chemical change, except by catalysis. It is both an oxidizing and a reducing agent, sometimes decomposing other bodies by its strong affinity for their oxygen, and at others yielding its own oxygen to increase theirs.

Applied in a concentrated form to the cuticle, it acts as a powerful vesicant; whereas the dilute solutions usually employed are as bland and non-irritating as water itself.

A solution representing twelve or fifteen volumes of oxygen ($2\frac{1}{2}$ to 3 per cent.) is both strong enough for medical use and sufficiently stable for ordinary purposes.

The preparation of H_2O_2 usually found on sale is an aqueous solution, slightly acidulated, and varying in strength from 1 to 3 per cent. (5 to 15 volumes). In appearance it can scarcely be distinguished from pure, distilled water. It is odorless, and although generally described as having a slightly acid taste, this quality is chiefly due to the trace of acids which it is found necessary to add to it in order to protect it from too easy decomposition.

A weak solution of hydrogen dioxide has been sold as ozone water; and it seems to have been shown that the various tests for ozone, proposed by chemists, are neither accurate nor conclusive. It is now claimed that dilute hydrogen dioxide

will, in certain chemical relations, do all that has been attributed to ozone. It is questioned whether the many atmospheric conditions heretofore ascribed to the latter are not in reality due to the former.

Its too abrupt decomposition into water and free oxygen is sometimes attended with explosive violence, and the oxygen liberated is always in a peculiarly active condition, affording, as above indicated, all the usual tests for ozone. It has even been asserted, by one or two chemists, that ozone and hydrogen dioxide are identical; that ozone is not merely an allotropic condition of oxygen, but is, unquestionably, a compound body; that it is, in fact, merely *vaporized* or *sublimated hydrogen dioxide.* Names are not mentioned, for the reason that they are not authorized; besides, it should be every innovator's prerogative to announce his own discoveries.

Richardson found that to defibrinated venous blood it imparts free oxygen, with evolution of heat and a change of color to bright red. In contact with fibrin and cellular tissue it also yields oxygen. Sugar and starch are decomposed by it, giving off carbonic acid. Albumen [gelatin], urea, and cutaneous tissue are not affected by it. Injected into the left cavities of the heart it restores the irritability of that organ, but has a contrary effect on the right cavities. Injected into the arteries immediately after death, it temporarily restores the contractility of the muscles and suspends cadaveric rigidity; also antagonizing the action of some drugs which produce muscular spasm.

His experiments led to the inference that it would be useful in the treatment of narcotic poisoning, as a local application in gangrenous ulcers, and as an internal remedy in low forms of fever. From his later clinical tests he found it of considerable value in chronic and subacute rheumatism; it also acts like iodine in the dispersion of scrofulous swellings, cuts short the paroxysms of whooping-cough, shortening the course of this disease better than any of the remedies in use, and promptly relieves the dyspnœa of chronic bronchitis. In phthisis it is an excellent remedy during the early stages, improving the digestion, and greatly facilitating the action of chalybeate and other remedies; while in the advanced stages it obviates the use of opiates and other vital depressants by relieving the dyspnœa and oppression of breathing without involving the reactions which are inevitable under the use of sedatives and narcotics.

In general he found it to improve digestion, and hence it is useful in all chronic conditions accompanied by indigestion and want of assimilation.

Some instances are cited in which its free or excessive use produced salivation, suggesting its possible substitution for mercury, in treating certain forms of constitutional disease.

Day reports cases of diabetes of three years' standing, which had resisted all other methods of treatment, wholly relieved by an ethereal solution of peroxide of hydrogen. But Pavy and others assert that while it diminishes the quantity of sugar and the volume of the urine it does not prevent a fatal termination.

Dr. Dayton,* who has experimented with peroxide of hydrogen, concludes that it is an energetic deodorant, a powerful antiseptic; that it is indicated in a vast category of maladies where the mucous membranes are affected; and that, employed in irrigations, it is superior to all other substances. At the present day there is a tendency to attribute to the presence of peroxide of hydrogen in the air the immunity from pulmonary affections enjoyed by persons dwelling near pine forests.

Commercially, it is largely used in bleaching hair (the "golden wash" of the shops), feathers, ivory, bone; for cleaning and bleaching old engravings and oil-paintings, and for decolorizing oil, wax, tobacco, etc.

This peculiar product of the laboratory, so comparatively little known as to seem unimportant, is one of the most effective disinfectants, antiseptics, germicides and sporicides yet discovered.

Compared with other antiseptics, much in vogue, it has been found, by Miguel and others, to be 40 per cent. more potent than mercuric bichloride, twenty times as powerful as salicylic acid, and sixty times as strong as carbolic acid. This seems fairly incredible, but careful and repeated tests place the fact beyond question.

As a disinfectant it acts by entering into combination with the offending matter, oxidizing and thus effectually destroying it, leaving no substituted odor in place of the one removed.

It is a germicide of scarcely less power, and, what is more important, is a certain and potent sporicide; whereas it is now well known that many active germicides are either weak or worthless as sporicides.

* N. Y. Med. Jour., 1884.

Van Tromp* finds that hydrogen dioxide, in solution of the strength of $\frac{5}{10000}$, kills anthrax spores in twenty-four hours, typhus bacilli in five minutes, and cholera bacilli in less than five minutes. A solution kept for forty days, at a temperature of from 68° to 75° F., still destroyed yellow-pus cocci in ten or eleven minutes. According to Miguel, but two known substances surpass it in antiseptic potency, and these are mercuric biniodide and the iodide of silver.

Notwithstanding its remarkable power for destroying low organisms, it is perfectly harmless, and not at all unpleasant to use,—an important consideration in these days of antiseptomania and microbephobia.

As used in therapeutics, its *modus operandi* is by yielding and setting free one equivalent of its oxygen, in a nascent and hyperactive state, the resulting compound being simple water.

A spray of dilute hydrogen dioxide will purify and disinfect a sick-room more effectually and more rapidly than perhaps any known substance, unless it be a current of pure nascent oxygen; which is essentially the same thing, deprived of the propulsive, solvent and distributive properties of the spray or aqueous element. It will promptly disinfect the excreta in all putrid forms of the exanthemata, quickly destroying all septic germs,—a result which cannot be accomplished by even a 10-per-cent. solution of carbolic acid.

It will in emergencies supply oxygen for respiration, in close rooms where ventilation is impossible, and may be made to cleanse and render aseptic the skin, hair, and clothing of patients and attendants, and the walls, floors, and furniture of sick-rooms and hospital wards.

Internally, it may be administered in doses of from half a drachm to two drachms of the 3-per-cent. solution, but should be further and freely diluted with water. It is indicated in gastric catarrh, in all low fevers with septic tendency, in pyæmia, septicæmia, and whenever there is a tendency to acid or putrescent fermentation.

It may be inhaled by means of any of the ordinary inhalers, the same being placed in a vessel of water heated to 120°–140° F. This method has been extensively resorted to by some practitioners as a "home treatment," when gaseous oxygen has been out of the question. Another available method is to nebulize

* Centralblatt für Bacterien, ii, 25.

the solution by means of compressed air from a receiver, or by any good hand-nebulizer, with a single or double bulb.

As a spray in surgical operations it is even more effective than carbolic acid or bichloride, while it is free from the disagreeable odor of the one and the corrosive properties of the other,—items of no little importance.

It is applicable direct to the simple as well as the specific ulcer, to sinuses and pyogenic membranes wherever found, and will decompose and destroy lymphous, aphthous, and pseudo-membranous deposits wherever a thorough application of it can be made; at the same time it has comparatively no action on healthy tissue.

When applied to the surface of a sloughing ulcer, not only is the pus destroyed, but the sore is thoroughly cleansed and rendered aseptic, so that healthy granulations may at once begin to appear. It is interesting to watch the action when a few drops of a proper solution is brought in direct contact with pus-corpuscles. Quoting the language of Dr. Shelly:* "A brisk effervescence at once commences and continues until all the pus is destroyed." The same authority states that this effervescent action on pus may be utilized as a test for pus in urine. If, however, blood be present in the suspected liquid, the same effervescent action takes place, so that the test is not entirely accurate; but it will be found valuable in some cases as a comparative and ready test for both pus and blood.

If applied to a foul and sloughing ulcer, an oozing carbuncle, or patch of incipient gangrene, its decomposition and the liberation of oxygen goes on under the eye of the observer as though it were sentient and semi-intelligent. As long as pus, sanious exudations, or fungoid growths are present, the bubbling evolution of oxygen [or ozone?] proceeds, and the wound is soon coated over with a fine white froth. As soon as the ulcer is fully cleansed and all morbid tissues destroyed, this effervescence ceases, nor will fresh applications reproduce it.

It has proved of especial value in mercurial stomatitis, and the removal of ordinary aphthous patches is hastened by its repeated topical application.

In the London *Medical Record* for March, 1883, Dr. E. C. Landolt reports excellent results in a large number of ophthalmic cases. In purulent ophthalmia, whether of simple or specific

* Practitioner (London); March, 1884.

origin, it acts promptly, soon rendering the surfaces clean and non-suppurating.

It is indicated in all septic, zymotic, and infectious conditions, in empyema, septicæmia, the typhoid state, etc., and it is suggested that it may prove valuable in gastric ulcer, carcinoma of any hollow viscus, and in all conditions involving degenerative lesions of the gastric or intestinal mucous membrane.

It has been recommended in diabetes, chronic Bright's disease, in many forms of the indigestions, and in chronic rheumatoid affections; but clinical experience is wanting in this latter direction. Le Blond reports nearly negative results in a few cases of diabetes.

From this glance at its properties and range of applicability, it would be at once inferred that at least one special field for the therapeutic use of hydrogen dioxide is in the direction of combating the national—if not universal—scourge, *diphtheria*. Accordingly, the clinical tests thus far made seem, in most instances, to corroborate the inference in the most positive terms.

Dr. R. J. Nunn, of the Savannah Hospital, has made as extensive trial of the remedy in connection with this fatal malady as any practitioner whose reports have been published. Briefly summarizing his results: when topically applied, thoroughly and early in the history of the disease, before systemic infection had too far progressed, and before the deposit had invaded inaccessible parts, using spray, douche and gargle, one or all, according to feasibility, the solution of hydrogen dioxide, of the strength of fifteen volumes, promptly decomposed and destroyed the membrane, and brought the cases to an early and favorable termination, apparently warding off all disastrous sequelæ. Dr. Nunn suggests that in some cases it may be found advisable to combine it with lime-water, or lactic acid, with a view to increasing its solvent and detergent power.

Dr. Shelly, in the paper already referred to, says of the peroxide: "Applied on absorbent wool as a swab or temporary dressing to venereal sores, foul or sluggish wounds, and purulent eczematous surfaces; used as an injection for abscess-cavities, purulent ophthalmia, otorrhœa, gonorrhœa, and leucorrhœa; used as a mouth-wash or gargle in case of dental abscess or caries, and in simple stomatitis; or directly applied to ulcerated surfaces on the tonsils and pharynx, and as a douche or injection in ozæna (the crusts having been first removed), it has

yielded most satisfactory results. Not only is it painless in itself, but I have noticed cases of painful and irritable ulcer in which, during its application, the pain notably abated, possibly attributable to the local anæsthetic action of the gas evolved during effervescence; for when the fluid acts on pus, carbon dioxide appears to be set free.

"Mixed with glycerin and applied on a tampon of absorbent wool to the ulcerated cervix uteri, it yields satisfactory results. On removing the tampon a few hours afterward, the ulcerated surface is found quite clean and free from discharge, and already wearing a more healthy appearance.

"I recommend the use of this agent," he adds, "which I know to possess powerful antiseptic properties, and, moreover, is colorless, odorless, cleansing, and stimulating, does not stain or corrode, destroys pus, causes no pain in its application, and is not poisonous."

Parallel with the experience of this author, the writer has used the remedy as a topical application in case of severe carbuncle, of sloughing ulcer situated in the ischio-rectal region, and in one case of septic poisoning by absorption during a tedious autopsy. In all these cases the action of the liquid solution used, of the strength of twelve volumes, was fairly brilliant, and far exceeded his expectations. The carbuncle was almost instantly relieved of its painful nature, and in a few days, by repeated applications, made a kindly and speedy recovery. The sloughing ulcer, although it had resisted for a long time all the numerous remedies which had been recommended, soon became clean, the indurations in the vicinity gradually softened, and healthy granulations were early apparent.

In the case of septic poisoning the most prominent point of the angry and fairly fulminant tumefaction was freely laid open and a twelve-volume solution of peroxide applied. A rapid effervescence ensued and the applications were repeated as long as this effect was observed. A thick compress of cotton-wool was then applied to the hand and wrist, for the œdema was rapidly extending toward the body, and this was kept saturated with the solution for twelve hours, by which time the appearance of the hand was very much changed. The severe pain and œdema were relieved, and, within two days, what was evidently the incipiency of a dangerous constitutional infection was quietly and completely aborted.

It has been found valuable as a topical application to many of the itching eruptions, such as urticaria, eczema rubrum, herpes labialis, and occasionally in psoriasis. It will almost invariably abort a common stye (hordeolus) if early applied, and will frequently disperse or discuss a threatened or incipient furunculus. Its combination with chemically pure glycerin, under the suggestive name of *glycozone*, is another promising and convenient form for using it externally, the chief drawback being the cost of this latter preparation. In aggravated cases of urticaria (of malarial origin) nothing that the writer has tried has given such prompt and pleasant results. In short, there is scarcely any limit to the useful and agreeable applications that can be made of this interesting but little-known agent.

It is evident that in pure hydrogen dioxide we have a source of free oxygen, and a remedy which must, ere long, occupy a much more important place in our armamentarium than has as yet been accorded to it.

The tests for proving the strength of a given solution of H_2O_2 are as follow: (1) As a ready and approximate test, place a few crystals of permanganate of potassium in a test-tube, a graduate or any convenient glass vessel of small size. Pour over these crystals one or two drams of the solution to be tested. The briskness and persistence of effervescence which follows will indicate the strength or weakness of the solution. (2) For an accurate or quantitative test make a standard test as follows: Dissolve 1.852 grams of potassium permanganate in distilled water and add water until it measures 500 c.c. Using this solution, each c.c. neutralized by a measured quantity of the H_2O_2 solution represents one volume of evolved or liberated oxygen. This standard permanganate solution is easily made, and may be kept for some time if excluded from the light.

(*b*) *Oxygen from Chemico-Vital Reactions and Decompositions.*—This is a department in the study of oxygen therapeutics which has been almost universally ignored. Only the most casual references to it can be found in medical literature. That many of our ordinary routine remedies, of high repute in every-day practice, act chiefly by imparting to the organism a portion of their oxygen, is not only plausible, but is also corroborated by analogy and by a more critical study of physiological chemistry. In certain instances it may be said that this result no longer admits of reasonable doubt.

It would be difficult to mention all the substances which may be reasonably claimed as belonging to this list, but a few of the more prominent ones may be cited:—

Chlorate and permanganate of potassium and peroxide of manganese, internally administered; all the mineral acids, many of the vegetable bitters—quinine, hydrastine, etc.; the terebinthinate group, including terebene, terpinol, terpene, etc., some of which, having no oxygen of their own, act indirectly by rapid absorption and subsequent surrender of this element.

Other substances act merely as distributers of oxygen; iron, for example, which has acquired a reputation beyond its inherent deserts, on account of the facility with which it becomes an *oxygen carrier*. Other metals possess the same property, but in a lesser degree.

Gold and nickel are being used and recommended internally, the good results, no doubt, depending wholly on their capacity as oxygen carriers. Neither of these metals belongs to the list of histological elements, hence it is fair to infer that their office in the human economy is that of carriers, mediators or servants, not of direct builders. This subject will well repay a much more thorough and extensive study than has yet been devoted to it.

(*c*) *Nitrogen Monoxide* (*Protoxide*).—Since Sir Humphry Davy asserted that nitrogen monoxide—then called protoxide of azote, and frequently called "laughing gas"—possessed therapeutic properties, its use as a transient anæsthetic has become so universal as to almost wholly overshadow all other uses. But that it has other properties than that of producing temporary exhilaration when diluted with air, and of temporary anæsthesia when administered in a pure or undiluted state, is now quite evident. The reasons for thus estimating it may be stated as of three kinds: theoretical, empirical, and rational.

Theoretically, it should be, to some extent, a vital oxidizer, from the fact that it supports combustion almost as well as oxygen itself. It is also far more soluble in water and all aqueous fluids than the latter gas. Empirically, it is found to allay spasm, relieve pain, relax nervous tension, and to induce a feeling of rest and exhilaration. Rationally, it might be accredited with therapeutic value from both its empirical and theoretical characteristics, assuming that it may be both directly and indirectly an oxidizer; the first, from its property of supporting

combustion, and secondarily from the readiness with which it may be induced to part with a portion of its oxygen. To what extent decomposition of this gas takes place within the animal economy cannot be accurately estimated; but that some decomposition of it does take place is plausibly asserted.

Finally, we must not lose sight of its moral or psychic effect on the patient. Many practitioners look upon it as a make-shift of quackery,—a mere placebo, of no more therapeutic value than the coating used to disguise the taste of a pill. This is a mistake. Whoever ignores a remedy simply because it appeals chiefly to the subjective sense of the patient, or to his credulity; or because, forsooth, quacks have too freely adopted it, makes a serious and senseless blunder.

This is the gas so long exploited as "compound oxygen." It has also been called "oxygenized air," "perfected oxygen," and by several other more or less fanciful and misleading names.

Of course it is not oxygen, but is a definite compound consisting of two atoms of nitrogen, in a state of chemical combination with one atom of oxygen.

By very many of those practitioners who have given some attention to the use of oxygen, nitrous oxide is not at all used. By itself, or except as a modifier of oxygen, it is not now used or recommended, as far as known, by any physician of note. As an adjuvant, and, to some extent, modifier of oxygen, it is used and approved by many who have earned professional repute in connection with oxygen therapeutics.

The usual mode of exhibiting this gas, therapeutically, is to add from 15 to 40 per cent. of it to pure oxygen, still further diluting this mixture with common air. Used in this strength it is found to add materially to the quieting and restful influence of oxygen. Aside from the palliative and soothing effects of this gas, empirical observation goes to show that, from its greater solubility in the blood, or for some other physical reason, it acts as a rapid distributer of oxygen, and thus indirectly, if not directly, energizes the action of the latter.

In all neurasthenic and neuralgic conditions it is a valuable adjunct and synergist of oxygen. In cases of insomnia it is a pleasant remedy, and generally acts efficiently. In these cases the proportion of this gas may be increased to 50 per cent. or more, with decided advantage. Unlike oxygen, nitrogen monoxide does not seem to deteriorate with age, nor does the act of

compression appreciably injure its quality; hence, it is quite feasible, as well as convenient, to procure it compressed to liquid form in cylinders, from which it may be dispensed at pleasure. At a pressure of fifty atmospheres it assumes the liquid form, and occupies very little space, a half-gallon flask easily holding the equivalent of one hundred gallons of the gas at its normal tension, under a pressure of one atmosphere.

The writer has recently made use of both oxygen and nitrogen monoxide as substitutes for common air in connection with atomizing and spraying apparatus. The former has not been used sufficiently to make the results entirely conclusive, but they are certainly promising. Of the monoxide more extensive use has been made, chiefly in connection with the dressing and treatment of painful and sloughing ulcers. In this direction it is a valuable addition to our surgical resources. The method of use is simple. A cylinder of the gas, compressed as for dental or other purposes, is connected by means of gas-tight rubber tubing with any good form of spray or atomizing tubes, and any antiseptic or detergent solution preferred by the operator is used. In most cases the peroxide of hydrogen is preferable, on account of its powerful action as a detergent and antiseptic, as well as on account of its non-irritant and non-toxic, properties. Nothing could be more satisfactory than the two combined. Each is evidently a synergist of the other. Both are, in a measure, locally anæsthetic, hence both allay irritation and contribute toward the relief of pain. In case of the angriest carbuncle the effect is fairly magical. The peroxide promptly destroys, by decomposing, the fetid exudate and fungoid growths, the pain is assuaged, and the healing process is rapidly induced. The strength of the solution must be properly regulated. In ordinary cases a 1 to 2 per cent. (5 to 10 volume) solution will be found strong enough. Occasionally a 15-volume (3 per cent.) solution will not be too strong, and will be found more effective.

The writer has also used nitrous oxide, mixed with 20 or 25 per cent. of oxygen, by ordinary inhalation, to prepare patients for the prolonged anæsthesia required in capital operations, and always with very happy effect. It lulls the patient's apprehensions concerning the more powerful anæsthetic to be used, and also materially lessens his dread of the operation. It also invariably mitigates, if it does not entirely obviate, the stage of excitement which usually occurs at a certain stage of

ether or chloroform administration. For this purpose it ought to command the attention of operating surgeons much more than it has yet done.

The most extensive and pretentious volume yet published on the subject of the medical uses of nitrogen monoxide was written by Dr. George J. Ziegler, of Philadelphia, and was published in 1865. Dr. Ziegler claims to have devoted more or less study to this agent during a period of sixteen years, and, as a result, indulges in over-enthusiastic and decidedly extravagant estimates of its hygienic and therapeutic value.

The following are among his conclusions: It may be regarded as a general truism that the greater the physiological compatibility of medicinal agents the greater their remedial efficiency. This vital compatibility is both of a material and dynamic nature. Thus, iron, lime, potash, and soda have an immediate material connection with the animal organism; quinia, strychnia, etc., have a direct dynamic relation thereto, while phosphorus and some similar agents subserve both material and dynamic purposes in connection with vital processes. Protoxide of nitrogen belongs to the latter class. Although different in composition from all other chemical bodies, it is, in the main, identical with atmospheric air, differing from the latter, however, both in the proportion of its constituent elements and in the character of their association. The proportions in nitrous oxide are, nitrogen two parts, oxygen one part; in atmospheric air, nitrogen four parts, to oxygen one part. In the former these elements are in a state of chemical combination; in the latter they are in a state of mere mechanical mixture. Hence, protoxide (monoxide) of nitrogen and common air, although differing in the relative proportion of their constituent elements and in the character of their association, are similar, varying in degree rather than in the nature of their affinitive reactions and physiological effects.

Nitrous oxide* is closely correlated with oxygen. It is, like atmospheric air and oxygen, an active supporter of combustion and of life [?], yet there are specific differences, emphasized more particularly in their vital influences, which render them appropriate for distinct though somewhat similar medical purposes.

* Dr. Ziegler uses the terms *nitrous oxide* and *protoxide of nitrogen* indiscriminately, instead of the more accurate and more recent term, *nitrogen monoxide*.—W.

The effects of protoxide of nitrogen on the human system vary in proportion to the quantity appropriated, the individual susceptibility, and the temporary condition of the organism, passing from a gentle acceleration of the functions to a high degree of physical excitement and mental exhilaration, amounting in the extreme to an intensely pleasurable delirium, which may indeed become an ecstasy so pure and exquisite as to absorb the consciousness of existence itself.

Taken freely, these sensations are enhanced, and are followed by buoyancy of spirits, boisterous gayety, active imagination, vivid flow of ideas, sublime mental conceptions, etc., etc. The stage of hyperexcitation, anæsthesia, and trance are, how ever, of brief duration, terminating suddenly, yet leaving a sense of invigoration rather than of languor and depression, as in the case of ordinary stimulants. It has also special tendencies to certain parts of the body, the blood, brain, nervous system, and genito-urinary organs. It exerts both a material and dynamic influence on the animal organism, its peculiar biological effects depending, doubtless, upon its constituent elements in their separate as well as combined state. Its potency is largely but not wholly derived from its oxygen,—a fact proved by the peculiarity of some of its effects, which are unknown in connection with the use of oxygen alone. Undergoing decomposition in the system, its peculiar effects result from the operation of both its constituents in a nascent or hyperactive condition. It both supplies essential material for organization, and promotes the general molecular, nutrient, reproductive, and dynamic operations of the animal economy. Hence, it promotes the various functions of digestion, absorption, circulation, aëration, hæmatosis, etc., etc.

A priori, an agent so potent in maintaining the system in its normal states should be efficient in correcting abnormal action, or want of action. It follows that this agent may be made an efficient substitute for such remedial agents as alcohol, ammonia, quassia, strychnia, and others classified as diffusible and permanent stimulants, tonics, antiperiodics, antispasmodics, and alteratives. It cannot, however, meet the necessities of the case where there is a privation of normal components of the economy other than those of its own constituents; in other words, it cannot replace the want of lime, soda. phosphorus. iron, etc.

In comprehensive terms, it is a direct nervous, cerebral, arterial, and general stimulant, a secernent, depurant, aphrodisiac, and antitoxic. The invigoration following its use, unlike that induced by other stimulants, is generally continuous, persistent, and without subsequent depression. It is especially indicated in indigestion and inefficient absorption, as also in general torpor of the chylopoietic functions, in neuralgia, chorea, paralysis, melancholia, amentia, and adynamic states generally. It is, moreover, strongly indicated in atonic conditions of the genito-urinary apparatus, such as incontinence, suppression, vesical paralysis, spermatorrhœa, impotence, sterility, some forms of amenorrhœa, dysmenorrhœa, etc., etc.

In certain stages of phthisis it is very useful in promoting assimilation and hæmatosis, and in relieving oppression of breathing, cough, and other distressing symptoms. In mild forms of glycosuria he has repeatedly seen the saccharine element rapidly disappear under the use of protoxide of nitrogen. It is contra-indicated in actively irritable and inflammatory states, especially of the cardiac, cerebral, hepatic, and renal organs. In Bright's disease it must be given with circumspection, since any excess of it may increase the tendency to uræmia. In the chronic stages of rheumatism and gout it is decidedly useful, but must be used moderately or not at all in the acute stages, lest it might increase the active inflammation.*

This agent may also be advantageously employed in asthma, cyanosis, asphyxia of the newborn, and in suspended animation generally. In such cases it aids by arterializing the blood, subverting the effects of noxious matters retained in the system, stimulating the nervous and invigorating the general system, and also by combining with or decomposing such deleterious substances as may be present and promoting their elimination. Thus, it is indicated in the ataxic and adynamic fevers, typhus, typhoid, congestive, yellow, remittent, and intermittent, as also in scarlet fever, measles, and diphtheria. It is valuable also in the treatment of chronic alcoholism, the opium and tobacco habits, and to overcome the poisonous effects of narcotics in general.

As an anæsthetic, protoxide of nitrogen is unique, differing

* This appears to be a reiteration of the same old saw referred to in connection with oxygen. It is probably nothing more than a reiteration, and entirely groundless.—W.

essentially from all other agents of the kind in its chemical constitution, physical properties, and physiological influences. Thus, most anæsthetics are composed essentially of hydrogen and carbon, while this is a compound of oxygen and nitrogen. The former produce insensibility by directly preventing aëration of and actually deoxidizing the blood, depressing the nervous system, stupefying the brain, and paralyzing the heart. Nitrous oxide, on the contrary, increases oxidation, stimulates the brain, augments general and special sensibility, invigorates the system, and acts not as a depressant, but as a true tonic. In a word, while chloroform and ether arrest vital processes, nitrous oxide promotes life action.

It may be asked, How is it then an anæsthetic? The answer is, that when taken freely, the physiological processes are accelerated to such a degree as to temporarily overcome systemic excitability. The anæsthetic effect of this gas, then, is the result of vital exaltation instead of depression. An intense ecstasy is induced which momentarily overcomes sensation, much as occurs in cases of intense emotional excitement, social, religious, or political, amounting to heroic passion and fanatical frenzy, as also in some forms of insanity, in hysteria, trance, etc.

The state of anæsthesia from nitrous oxide is, however, usually of very brief duration, terminating suddenly in from one to three minutes. Its eligibility is therefore much less than that of other anæsthetics, since it can be used only for minor and short operations. Nor must it be used carelessly, but always with careful discrimination, as an anæsthetic, since in certain conditions of the system it is capable of doing serious harm.

VII. IMPROVEMENTS IN APPARATUS.

The negative, and in some cases untoward, results reported by experimenters with oxygen have, without doubt, been largely due to imperfect facilities for evolving pure gas, and to carelessness in manipulation. Inefficient apparatus, in the hands of over-busy or careless practitioners, readily accounts for a host of reputed short-comings. But even the overworked physician is not excusable if he is content to measure the therapeutic value of oxygen by the results supervening upon the use of either large or small quantities of carelessly generated and half-washed gas. Nor is he to be exonerated if, after undertaking to utilize oxygen in his practice, he fails to equip himself with the

most efficient appliances to be had for its evolution in the purest condition attainable.

Since Demarquay wrote his work various modifications and improvements have been made in the forms of apparatus used, the more important of which will be noted.

(*a*) *Retorts.*—Instead of the heavy crucibles of cast or wrought iron formerly employed, sheet-metal retorts are now

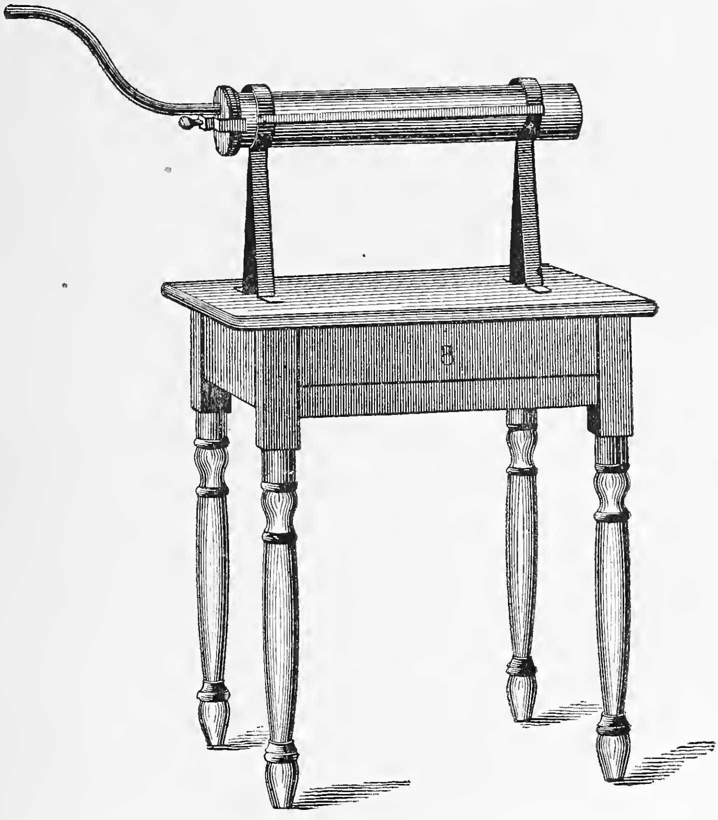


FIG. 11.—CYLINDRICAL OXYGEN RETORT AND FRAME.

quite generally used. These are made of iron, brass, or copper, in several different forms, viz., pear-shaped (made only of brass or copper), conical, and cylindrical. Iron is the preferable material, for two reasons. It is least expensive, and resists the corrosive influence of the chemicals used, and of hot oxygen gas, much better than copper or brass. Copper and brass retorts are usually made pear-shape, from the fact that this is one of the

readiest forms for metal-spinners to manipulate. It is, however, the poorest possible form for the purpose, causing all the material to fuse at about the same moment, and in consequence the gas is evolved with such suddenness and rapidity that it severely tries the connections, and there is also more danger of overheating the material. The conical form, with flat bottom, is far preferable. In this form the material can be decomposed more gradually by heating one side or portion at a time.

For larger quantities than forty or fifty gallons of gas at a time, cylindrical retorts are preferable. Sheet-iron is the best material for these, up to a capacity of one hundred to one hundred and fifty gallons at a heating. For larger quantities wrought-iron is better adapted, the most available form being made from boiler-flue tubing, or from light-weight gas-pipe of the desired calibre. For larger quantities of gas—five hundred to one thousand gallons at a heating—six-inch tubing is an available size, the capacity being governed by the length, which may be from two to six feet, according to the capacity desired. In large retorts it is well to provide two or more outlet-tubes, to guard against the accidental obstruction of a single one. Each outlet-tube should have its own separate set of wash-bottles, but two tubes may be arranged to communicate with the same set. Cylindrical retorts should have one end adapted with a collar to which a head can be fitted by a ground joint, gas-tight, and held in position by a clamp and set-screw.

Outlet-tubes should have good calibre,—three-eighths to one inch, according to size,—to obviate liability to choke, and should be long enough so that the gas will not heat them sufficiently to injure the rubber connecting-tubes.

(*b*) *Wash-Bottles.*—For stationary use these may be of liberal size—from one to two gallons. They are to be fitted with rubber stoppers perforated to receive the conducting-tubes, which may be of glass or hard rubber. Glass is unexceptionable as to its effect on the gas, but it is fragile, and often gets broken at a critical moment. Hard rubber is more economical, and, after a few days' immersion in a caustic solution, or rinsing with alcohol, it does not impart any appreciable taste of rubber to the gas. These tubes should be of fair calibre so as not to impede the gas too much in its flow.

Within a year or two an important improvement has been made in the form of wash-bottle tubes used to conduct the gas

to the bottom of the purifying solutions. Instead of the ordinary open-end tubes which discharge the passing gas in large bubbles, of which only the outer surfaces come in contact with the washing fluid, the extreme bottom ends of these tubes are expanded into a bulb, which is pierced with numerous minute holes. By this device the gas is fairly pulverized and caused to escape in bubbles so small that, when the process of evolution is in actual progress, they have the appearance of a white froth. This insures an incalculably greater contact of the gas with the washing fluids than occurs with the ordinary tubes in use. The contrast will be apparent when we compute the difference between the superficial area of a single bubble of, perhaps, one inch in diameter, with that of the same bubble when broken up into a thousand miniature bubbles. The difference is, as stated, almost incalculable; and one wash-bottle provided with these bulb-end tubes actually washes the gas as effectually as a dozen

FIG. 12.—HARD-RUBBER WASH-BOTTLE TUBE (HALF SIZE).

or more ordinary wash-bottles. A little reflection will satisfy the merest novice in physics that this is an item of immense practical importance. Armed with this form of tube, a wash-bottle of small size will more effectually purify gas passing through it than even the largest size not thus provided.

The following is a good arrangement for a stationary office apparatus:—

Six wash-jars, the first one to be used empty. This empty jar acts as a safeguard against a reflow of fluid into the retort, in case of accident during the process, or negligence in disconnecting the outlet-tube after an operation.

The second and third wash-bottles are to be two-thirds filled with a rather strong solution of caustic soda, ʒss–ʒj to the gallon, or one may contain a similar solution of caustic potash, or "milk-of-lime," as recommended by Demarquay.* This

* By "milk-of-lime" is evidently meant thin whitewash, and not mere lime-water.

should be made from the freshly calcined article known as quicklime.

No. 4 is to contain a solution of ferrous sulphate, ℥ij to the gallon, to which ℥ij of commercial sulphuric acid is to be added.

In lieu of ferrous sulphate some chemists prefer a weak solution of nitrate of silver, ʒss to the pint.

No. 5 may also be a silver solution, or a weak solution of permanganate of potash, ʒj to the gallon, or simply pure water. No. 6 is to be fitted with tubes the same as regular wash-bottles, but instead of containing a washing solution is to be quite compactly filled with absorbent cotton, which acts as a final filter for the gas. This idea of a filter is of quite recent origin, and materially adds to the efficiency of the apparatus. It intercepts and detains particles of sublimed material which almost unaccountably elude the solutions in the wash-bottles.

This arrangement forms a very efficient safeguard for the removal of impurities and by-products evolved during the process of gas-making. It may be varied somewhat to suit individual ideas, and to meet the exigencies of different cases; but no arrangement which includes only one or two wash-bottles can be made effectual for the purpose. (It is patent to every reader of Demarquay's work, that his gas was frequently, if not invariably, tainted with traces of chlorine and other deleterious impurities. This fact accounts for various symptoms and results which he noted, but which would otherwise be unaccountable.)

(c) *Gas-Holders.*—For immediate or temporary use any convenient receptacle will answer, the cheapest and most portable for bedside and emergency use being rubber bags or balloons. These should be made of pure gum; adulterated rubber and rubber cloth being poor substitutes, for the reason that bags made from these materials permit transudation of the gases, sooner or later leak, and it is impossible to repair them. Besides, they do not give satisfactory wear, even if gas-tight at the start, which they seldom are.

These rubber bags, as to shape, are made oval, spherical, and cylindrical, the two latter being the preferable forms. They should be encased, each in a light cloth cover, of any suitable material, which prevents overdistension, and makes them less disagreeable to the touch. In case of damage to a pure gum bag it can be readily repaired by removing the cloth cover and applying patches of thin rubber, using rubber cement, which

can now be had in the market. The most convenient sizes for portable use hold from five to ten gallons.

Metal gasometers, having a capacity of from fifty to one hundred gallons, are generally adopted for office use when other

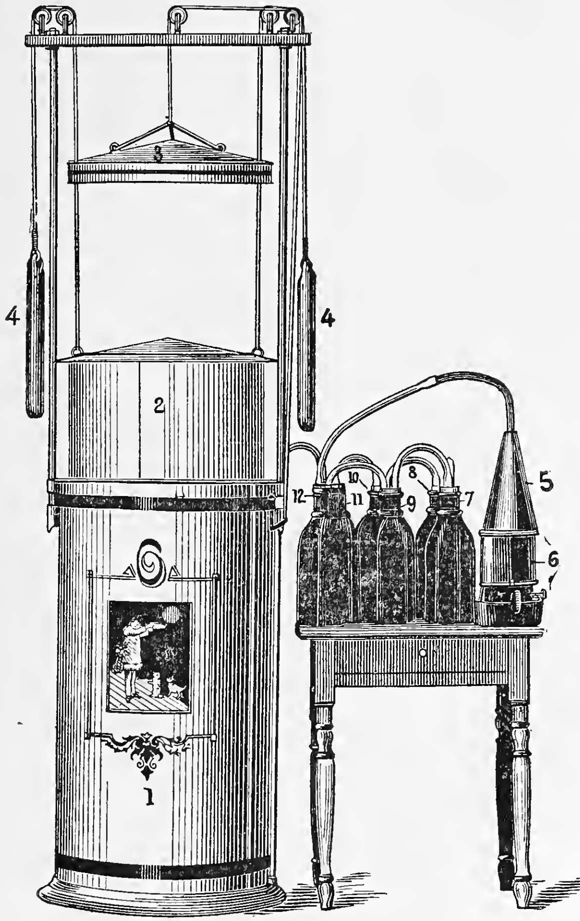


FIG. 13.—STORAGE GASOMETER (50 GALLONS) WITH RETORT, KEROSENE HEATER, AND SET OF SIX WASH-BOTTLES, FOR GENERATING, PURIFYING, AND STORING OXYGEN.
1, tank; 2, bell; 3, depression weight; 4, 4, balance weights; 5, retort; 6, heater; 7, 8, 9, 10, 11, 12, wash-bottles.

than small quantities of gas are needed. Zinc and galvanized iron are both used, the latter being preferable, because stronger and more durable. The best forms have self-supporting frames, with cords, pulleys and weights adapted to balance the weight

of the bell or gas-holder proper, as it rises and falls. An additional convenience, which has been devised with a view to dispense with the cost of a pump for transferring gas from the gasometer to a bag, or for any other purpose, consists of a suspended weight, which, also provided with cord and pulley, can be raised and lowered at will. Thus, when gas is being evolved, it is

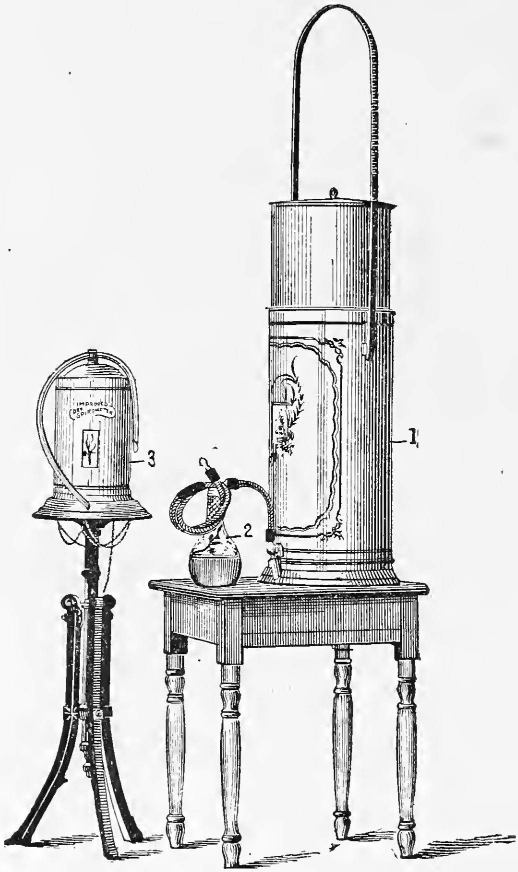


FIG. 14.—DISPENSING GASOMETER, SPIROMETER, ETC.
1, dispensing gasometer; 2, inhaling flask and connections; 3, dry spirometer.

raised to the top of the frame and fastened there. As it is often necessary to fill a bag, to transfer gas from one storage receiver to another or to a dispensing gasometer, or perhaps to assist a weakly patient to take deep inspirations, it will be seen that

this depression-weight can be made to serve a varied number of useful purposes.

In office practice a small dispensing gasometer is a further convenience, and for accurate work is almost indispensable. One holding six to eight gallons is large enough. It should have an attached scale or gauge for accurately measuring the gas as inhaled. (See Fig. 14.)

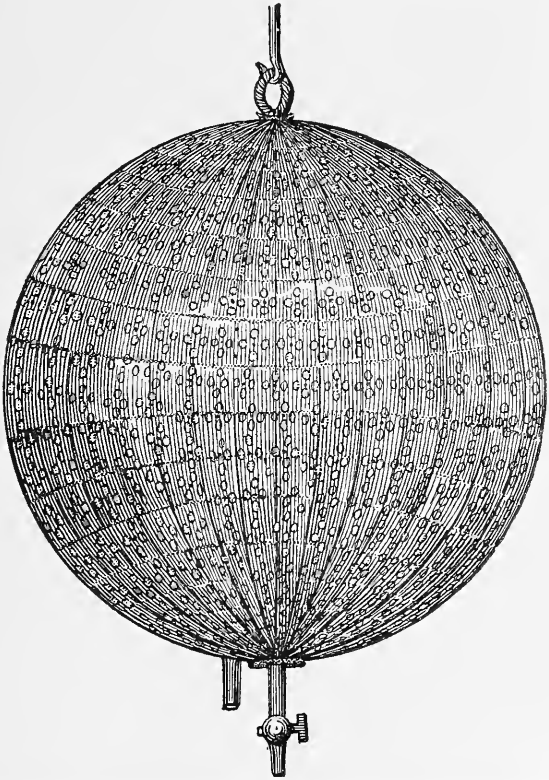


Fig. 15.—Spherical Gas-Holder (30 Gallons), Pure Rubber, Encased in Fancy Cloth, According to Taste.

The fifty-gallon size of storage gasometer is preferable for ordinary purposes, rather than the larger sizes, duplicating their number when greater capacity is needed.

To do away with the necessity for metallic storage gasometers, the writer has had balloons made of pure Para rubber, with a capacity of thirty gallons, to be neatly encased in cloth, both as a matter of taste and for the sake of protecting them from injury

from overdistension and from handling. This balloon may be made of actual balloon shape, in the form of a sphere, or in any form preferred, and is to be suspended from the wall or ceiling. When empty it will take up no room, and when distended with gas it will be rather ornamental than otherwise. Its complete portability is also another important advantage. It is to be provided with inlet and outlet tubes, and can be transported to the bedside of an emergency case, where, by rapid use of a reliable portable generator, a large and constant supply of the gas can be kept at hand.

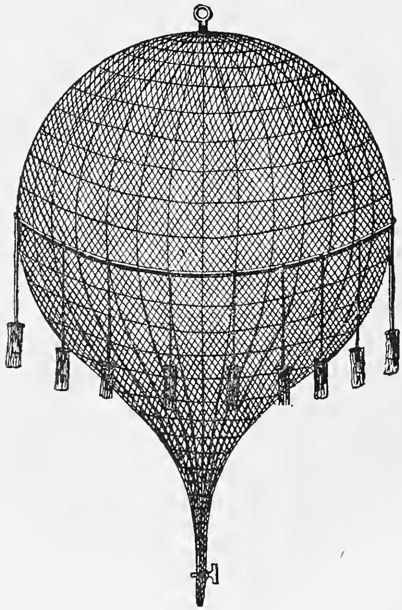


FIG. 16.—BALLOON-SHAPED GAS-HOLDER (30 GALLONS) ENCLOSED IN NET-WORK.

All rubber appliances should be frequently rinsed with a weak solution of soda or other alkali, or with dilute alcohol, 4 or 5 parts water to 1 of alcohol.

(*d*) *Inhaling Appliances.*—The gases may be inhaled directly from any form of receiver or gas-holder used, but it is better to interpose between the patient and the gas-holder an

Inhaling Flask, which serves both as an additional wash-bottle and as a substitute for a stop-cock. This flask may be plain or ornamental, according to the taste of the user. That

known as the *narghile* is the most pretentious, but some forms of modern water-bottles, which have rather long and wide necks without flaring lips, answer very well for this purpose. The essentials are a broad base, so as to be not easily overturned; depth sufficient so that the contained solution will not spatter into the outlet-tube when being used; a neck adapted to the

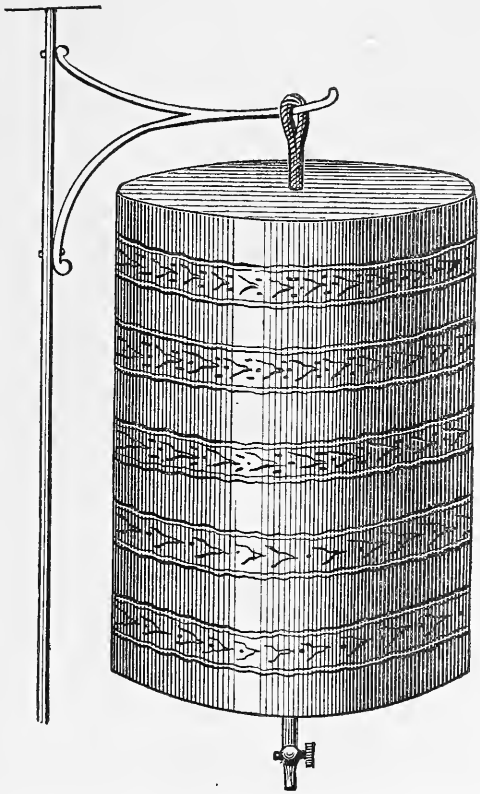


FIG. 17.—CYLINDRICAL GAS-HOLDER (ANY SIZE), PURE RUBBER, CLOTH-COVERED, SUSPENDED FROM WALL-BRACKET.

proper cork, and a capacity of from one to two quarts. A smaller size will answer for use with portable apparatus; and in emergencies any form of rather deep bottle with wide mouth may be utilized.

This inhaling flask, as above indicated, acts as a trap, obviating the necessity for turning a stop-cock after each inspiration. It also permits the use of any medicated, antiseptic, or aromatic

solution desired, as tar-water, menthol, iodine, creasote, carbolic acid, lime-water, oil of turpentine, chloroform-water, etc., etc.

No definite rule or formula need be given. Each practitioner must use his own judgment and tact to meet the indications in the case before him. It will, however, be well to bear in mind that the passage of nascent oxygen through solutions containing oxidizable matter may change these into new compounds by further oxidizing them. The solutions used should, therefore, be frequently renewed.

(*e*) *Mouth-Pieces.*—These are usually made of glass, but may be of celluloid, hard rubber, ivory, bone, wood, or any other suitable material. On the score of cleanliness, no material answers the purpose so well as glass. The form is not material, some operators using plain round tubes of proper calibre, the ends having been fused and made smooth for contact with the lips or nares.

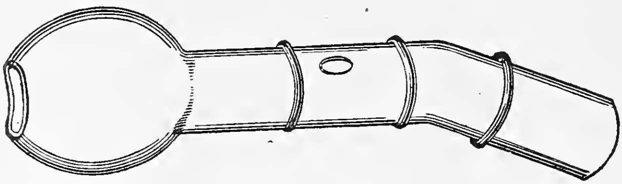


FIG. 18.—GLASS MOUTH-PIECE (FULL SIZE), WITH APERTURE FOR AUTOMATIC DILUTION OF GAS AS INHALED.

To obviate the necessity for diluting the gas before it is inhaled, the writer has devised a mouth-piece having a small vent or aperture, through which air is automatically admitted during the inspiration of gas. Fig. 18 illustrates this idea.

In many cases, in fact at all times when the nasal passages are free, it is better that the gas be inhaled through these passages.

VIII. PORTABLE APPARATUS.

It is now entirely feasible for every practitioner to be prepared to avail himself of the aid of oxygen in every serious emergency, whether he cares to use it in the treatment of chronic ailments or not. This removes the chief obstacle to a far more general recourse to this valuable and very often indispensable ally to other treatment.

By means of the bulb-end pinhole-perforated wash-bottle tubes previously described, coupled with a convenient, compact,

and at the same time quick-working and efficient generating device, a sufficient volume of well-washed gas for all ordinary emergencies can be prepared, in a very few minutes, by means of an apparatus no larger than an ordinary medical battery, and requiring even less skill in its management than the latter.

The accomplishment of this desirable and important result has occupied the writer's earnest attention for some years, and, ably assisted by expert mechanics, the result has exceeded the most sanguine hopes, and is, in fact, all that could be desired.

Fig. 19 illustrates the smaller of two sizes designed to meet the requirements of a moderate practice. This instrument is contained in a case eleven inches long, six and a half inches wide, and ten inches in depth, and suffices to furnish, at ten minutes' notice, fifteen hundred cubic inches of pure oxygen.

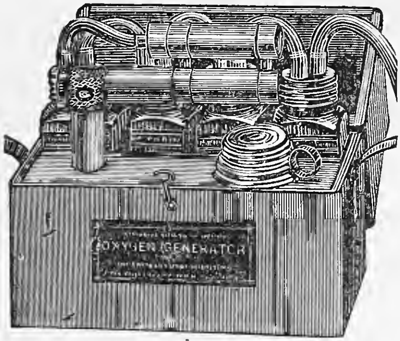


FIG. 19.—PORTABLE OXYGEN GENERATOR. CAPACITY, 7 GALLONS EVERY 15 MINUTES.

This quantity is sufficient for any immediate emergency, and may be repeated every ten or fifteen minutes, at will.

Fig. 20 illustrates the larger of the two sizes mentioned, and affords two thousand five hundred cubic inches of oxygen at each operation. By a duplicate arrangement two retorts may be used at the same time, or at the proper interval to make the evolution of gas practically continuous.

By taking pains to renew the solutions in the wash-bottles as often as they become foul or tainted, and using pure chemicals, either of these compact and readily portable instruments will supply any reasonable quantity of gas, of unexceptionable quality, for use in the office or at the bedside of the patient. They may be used with rubber receivers, for the sake of portability, or with any desired form of gas-holder. The dispensing gas-

ometer (Fig. 20) is a very convenient and appropriate companion for either of the portable generators shown.

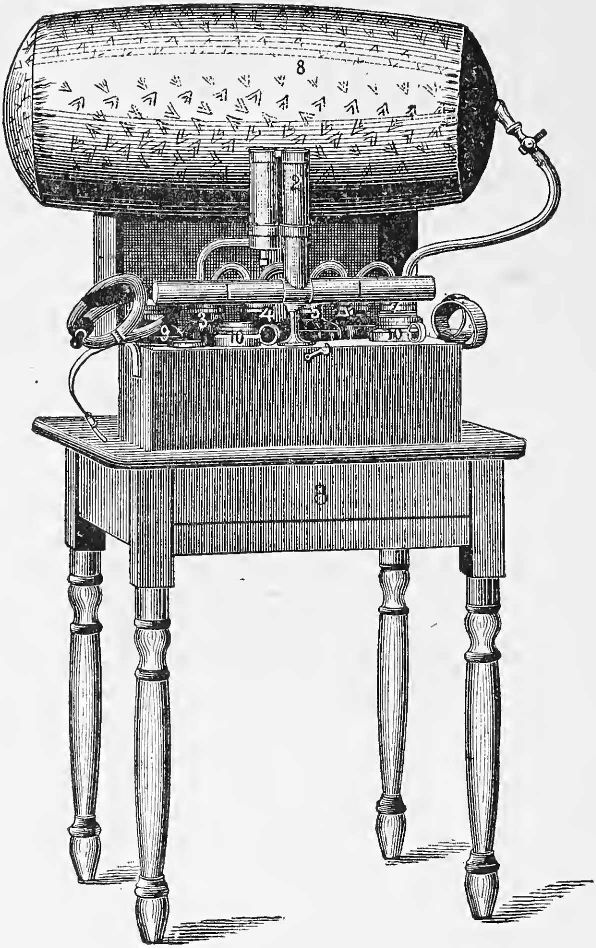


FIG. 20.—PORTABLE OXYGEN GENERATOR (LARGER SIZE). CAPACITY, 12 GALLONS EVERY 15 MINUTES, OR A CONSTANT FLOW, AS DESIRED.

1, 1, retorts; 2, cooler; 3, 4, 5, 6, 7, wash-bottles; 8, rubber gas-holder; 9, inhaling bottle; 10, 10, lamps.

IX. ACCESSORIES AND AUXILIARIES.

As with all novel or unusual methods of treatment, too many experimenters grow enthusiastic over oxygen, and, as a consequence, soon lose sight of other rational and indicated

means. Hobby-riding, although sometimes necessary and commendable, has often been a serious hindrance to medical progress; and hobby-riders, as a rule, are as inconstant as they are inconsistent. Many of them seem to lack capacity for more than one idea at a time. They harp, early and late, on water or air, quinine or bichloride of mercury, massage or galvanism, antipyrin or intubation, changing their idols as often as a "new remedy" is foisted into momentary notice.

As essential to all good practice, and especially applicable during a course of oxygen treatment, a few points are suggested:—

(*a*) *The Breathing Habit.*—In most chronic diseases there is a lack of breathing capacity, or there is a want of utilization of that capacity. No matter whether the diagnosis is phthisis or dyspepsia, pyæmia or asthma, increased breathing capacity, or a thorough development of that already possessed, but not efficiently used, is a desideratum.

Various methods have been more or less in vogue, having for an object the development of lung capacity and respiratory vigor. The readiest form of chest gymnastics may be had through the use of a good spirometer. Various forms of both the wet and dry varieties of these instruments are in the market. The latter are most convenient, and, if properly made, are as accurate as need be for all practical purposes. Some authorities prefer the wet variety—a bell, suspended over water, after the pattern of a miniature gasometer—as being absolutely accurate in its measurements; but, unless kept carefully adjusted, this form is scarcely more exact than the dry variety, as recently improved. Whichever form is used, if the exercise be well-timed and systematically persistent, the results attained will often be surprising, and are, as far as the writer's experience goes, invariably salutary and lasting. Collapsed and dormant lung-tissue is restored to use, and the respiratory muscles, which are practically far more important than any assumed "respiratory centres," since they are so much more tangible, are developed and decidedly strengthened.

(*b*) *Exercise.*—Every practitioner will at once recognize the rational need for increased muscular activity during a period of increased respiratory activity. Therefore do not neglect this essential factor. If the patient is able, let him walk, daily, two to ten miles, rain or shine, out of doors, if possible, in the house

(well ventilated), or on the veranda, if need be; but, at all events, somewhere. Let him climb mountains (hills, if there are no mountains within reach), row on the water, ride on horseback (carriage-riding is only a poor substitute), play at tennis or croquet, hoe in the garden, saw wood, rake hay, gather berries or nuts, or go fishing, hunting, or botanizing; and by all means let the exercise *interest* him or her, and not become a task or a mere enforced health-penance. Walking simply from a sense of duty might as well be done by a patent walking-machine.

If the patient be too feeble for any form of active exercise, then movement-cure and massage must come to the rescue. It is a department of medicine which is yet sadly neglected. Few physicians appreciate its almost immeasurable capacities for good.

Besides the innumerable methods of utilizing movements, both active and passive, there should be observed a regular system of chest gymnastics. For this purpose deep breathing is the prime essential, and, to give point to this, exercise with the spirometer, as already mentioned, will be found invaluable. But deep-breathing efforts should not be limited to a few minutes' daily practice with the spirometer. Exercise with light dumb-bells or clubs, gymnastic movements, every form of gesturing and posturing, done in the open air, or with the windows and doors thrown wide open, will aid in developing the capacity of the lungs, and thereby score a permanent and important benefit for the patient.

The "Pneumo-siren," an ingenious instrument for testing and practicing the breathing organs, devised some years since, but never much used by the profession, ought to be better known than it is. A cheap and yet very effective spirometer can also be easily arranged by any one, at slight expense, as follows:—

Fit a rubber stopper with a short and a long glass tube, and insert it into the neck of a one-gallon glass jar, as if for an ordinary wash-bottle. Fill the jar nearly full of colored water, and connect the long tube with several lengths of glass tubing by means of short lengths of heavy rubber tubing. Erect this tube in the corner of the room or beside a book-case, fastening it to the wall (or book-case) by a few loops of wire, fancy ribbon, or other support. The total height should not be less than nine or ten feet. To the short tube of the jar attach three or four feet of rubber tubing, and insert a mouth-piece in the free end. By blowing into this mouth-piece forcibly, the colored

water will rise to a certain height in the long upright tube. A scale can be arranged, marked in degrees of any desired interval (say, one, two, or four inches), with figures attached. For office use test the fixture by some gauged spirometer, or by causing some one, whose expiratory capacity has been thus tested, to blow to his full capacity, marking the point to which he raises the fluid, and gauging the tube both upward and downward from this point. If arranged as a home apparatus, or for a particular patient, let this patient's first effort establish a unity or zero-point, above which the scale is to be marked in inches. It will thus be easy to note his increase of lung capacity and chest power, from day to day and from week to week.

The ordinary dry spirometer is, of course, more convenient and more accurate, but the above will answer for securing the exercise in the absence of any better device.

(c) *Alimentation.*—Demarquay seems to have practically recognized the importance of this auxiliary, but he says very little about it. During an oxygen course it is more than usually important that the patient shall be liberally supplied with a judiciously selected diet, so that the processes of increased assimilation and repair which are generally inaugurated shall not be retarded for want of a free supply of the proper elements in available form. Oxygen promotes metamorphosis—tissue change, absorption, assimilation—the formation of protoplasm; but as bricks cannot be made without straw, tissue cannot be renewed without material. In meeting this demand it is more a question of quality than quantity, since overfeeding has fairly become as much a modern "fad" in the profession as it is an unwittingly disastrous habit in the community.

The average dietary already contains a redundancy of starchy, saccharine, and nitrogenous elements. It is therefore not these but the earthy elements which are especially in demand —the phosphates, carbonates, and chlorides. In anæmic cases attention to this point is imperative. It is a good rule to place these patients on some soluble form of combined phosphates —soda, potash, lime, iron; and it is gratifying to note the improvement which is soon manifest, and which without oxygen would not follow the use of these, properly speaking, remedies of nutrition. Nor would the use of oxygen unaccompanied by these needed elements meet the requirements. The relation between the oxygen inspired, ingested, and absorbed, and the

aliment taken, should be at all times carefully observed. To increase one and ignore the other is to fail of the best results. Do not forget that patients dying of chronic diseases virtually die of inanition,—starvation.

The two hydra-headed monsters, which annually devour their legions and despoil the brightest family circles in the land, with relentless regularity, are consumption and dyspepsia. The consumptives all die, virtually, *for want of available nourishment;* and this, in spite of the fact that we ply them with every sort of food preparation, dainty, and concoction which money can buy. Though fairly surfeited with viands, they gradually famish before our very eyes, and we feel ourselves powerless to stay the inevitable end. Now, the vaunted bacillus tuberculosis may be invariably present in phthisis, and intimately associated with the pathógnomony of the disease; but there is no fact better established than that no germ thrives in soil which has not first been prepared for its favorable reception. Phthisis may exist without the overestimated bacillus; but it never exists without the lowered vital condition—that marked depravation of the tissues which is the direct sequence of *innutrition.*

To nourish a human being, two things are necessary. First, that food of proper quality shall be supplied in due measure. Second, that means shall be taken to see that it is *properly digested and assimilated.*

We know exactly how to feed our track horses and our prize bulls, in order to make the most of their points; we know how to fatten pigs and geese and turkeys. We can even supply a developing dietary for stupid mollusks at the bottom of the Chesapeake Bay, but we make a flat failure of feeding the human dyspeptic and consumptive. In spite of the hundreds of flourishing proprietary food factories in the country, the one goes on suffering and the other goes on dying. To relax effort and passively assume that there is no remedy, is to confess that our art is a stupid delusion.

The countless army of digestion-fagged and lung-collapsed consumptives, like the poor, alas! we have always with us. How shall we nourish them? They loathe what we urge upon them, because they cannot utilize it; yet they are slowly starving for want of it. *Evidently we must make them competent to digest it.*

For a quarter of a century the physiologists have dinned it

into our unheeding ears that "in the animal body the carbon and hydrogen of the vegetable are again brought into contact with the oxygen from which they had been divorced, and which is now supplied by the lungs. . . . . We see, then, of what vital consequence is the presence of oxygen in the atmosphere. Without it fires and lights will not burn, *our food will not digest*, and the blood remains unpurified, as is shown by the pale faces and purple lips of people living in close, warm rooms." (Tyndall.)

In the light of modern science, nothing promises so much for the future treatment of phthisis as the practical carrying out of this suggested conjunction, viz., the systematic use of some approach toward an ideal nutriment,—*per os* when it is feasible, and *per rectum* when it must be so,—conjoined with the equally *systematic introduction of an increased supply of free and active oxygen.*

The three vital and all-important points at present virtually ignored are these:—

1. The selection, for the victims of wasting diseases, of a dietary which does not lack any of the essential elements of nutrition, which can be used indefinitely and by any admissible method of introduction, and which has been in some cases partially predigested.

2. The practical recognition and regulation of the *necessary relation between the food ingested and the oxygen inspired*, theoretically insisted upon by all physio-chemists and physiologists, without exception.

3. To exhibit both or either of these principles through the natural and usual avenues when they can be thus thoroughly utilized and assimilated, but to resort without hesitation to other feasible avenues when either the stomach or the respiratory function is, from any cause, seriously interfered with or impaired.

And if the medical profession, as a whole, will give to these admitted but unheeded physiological postulates a modicum of the study and interest now expended on bacillus staining and microscopic minutiæ, the death-rate from phthisis and other wasting diseases will be lowered during the coming decade, even more than has thus far been accomplished by the overdone (because not thoroughly done?) cod-liver-oil-and-hypophosphites practice; more than can be done with these agents, used in the ordinary way, even though Churchill's ghost should return to

organize a hypophosphite "trust," and all the cod in Norway should freely contribute their hypertrophied livers to supply the unctuous nauseant.

In brief, the diet must be nutritious and easy of digestion as to quality, liberal and satisfying as to quantity.

Another point is urged, viz., that there be at all times, during an oxygen course, very free ingestion of liquids. The character of these may be varied to suit individual cases, keeping in mind Demarquay's suggestion that a slightly alkaline condition of the blood at all times favors the absorption of the gas. The hot-water drinking mania, when not indulged to excess, greatly favors elimination, and should be decidedly encouraged. On the contrary, iced drinks should be interdicted.

(*d*) *Attention to the Emunctories.*—The increased activity of all the functions which ordinarily follows the judicious use of oxygen calls for increased attention to the emunctories. The bowels and kidneys usually take care of themselves, both constipation and scanty secretion of urine being gradually relieved, but the skin needs active and constant attention. There should be a semi-weekly hot bath, also made mildly alkaline by the use of borax, or soda and ammonia, to be followed by a cool, but not *cold*, dash and vigorous rubbing. In some cases inunctions of oil or some nutritive emollient will be found to add greatly to the progress of the cure. In patients greatly emaciated, warm milk baths, preceded by rapid sponging with hot water containing a little ammonia or alcohol, to open the pores and arouse an active cutaneous circulation, may be ordered, with gratifying results. Cod-liver oil may also be used by inunction in these cases. It would be better, in many cases, to exhibit it by cutaneous absorption, or by enema, as elsewhere set forth, rather than to upset the digestion of everything else by ordering the patient to swallow the nauseating stuff.

X. GENERAL SUGGESTIONS.

(*a*) *The Exclusive Mistake.*—Many well-meaning experimenters with oxygen are inclined to relax all their efforts to discover and intelligently meet general indications, as they arise, by a resort to other rational means. They devolve everything upon the gas, acquiring and perhaps courting the reputation of oxygen "specialists." They both expect too much of the agent and claim too much as its results. They thus

lose caste with the more thoughtful men of the profession, and narrow their own spheres of usefulness. Their experience adds little or nothing to the fund of either scientific or clinical data on the subject, since their efforts savor too much of "the shop" and of an effort at personal notoriety, regardless of candor, so that their evidence and their opinions have little weight with professional readers.

For this reason "oxygen parlors" and oxygen specialists are professional mistakes. Let "vital air" stand for all it is worth, but recognize in it only a rational aid, a natural weapon in the therapeutic field, sometimes to be relied on to the exclusion of others; oftener to precede, assist, or supplement them. That practitioner who administers a little oxygen once or twice a day, or who recklessly crowds the treatment to five times its reasonable limits, and then watches with open-eyed wonder for miracles to result, is no better than the most blatant and plausible of the quacks who crowd the religious and secular weeklies and monthlies with their lying but ingenious advertisements. Besides, he is not half so shrewd as the latter, of whom it may at least be said that—

> "The jingling of the guinea helps the hurt that honor feels."

It may be well, and it is quite appropriate and entirely ethical, to announce to professional brethren in your vicinity that you have provided yourself with ample facilities for preparing and administering oxygen and its congeners, in the most approved methods, but any other form of special advertising, as the profession now looks upon it, is not in good taste.

Make no loud claims, and if you do not roll in wealth as a result of your practice, you will at least have the satisfaction of retaining your own self-respect and an honorable standing among professional brethren.

(*b*) *Selection of Cases.*—Practitioners who desire to avail themselves of this agent should study well their cases, and carefully avoid recommending an oxygen course when not clearly indicated, when it is more than probable that no line of treatment will be faithfully followed, or when some other course of treatment is evidently more appropriate. Moreover, having advised a trial of the gas, do not therefore relinquish other rational aids which your unbiased judgment would approve, if oxygen had never been thought of in the case.

Give careful and constant attention to the regimen, the habits of exercise, and to the social influences surrounding the patient. Watch and record the pulse and respiration rates; note the condition of the secretions, the quantity and quality of the excretions, especially those of the skin and kidneys. Test the specific gravity of the urine daily (oxygen at first increases it). Keep it at about the normal standard, by directing an increase or reduction, as the case may be, of the quantity of liquids imbibed. Insist upon a careful observance of all recognized hygienic laws, the avoidance of all mental, moral, or physical causes of depression; and after it has once been decided upon, by all means insist upon a fair and reasonably thorough trial of the agent. When this is not feasible, or not conceded by the patient, better peremptorily decline to treat the case. At the very least, refuse to trifle with the remedy by making a hap-hazard use of it. Above all, do not forget that an increased absorption of oxygen invariably calls for at least three things:—

1. Increased alimentation,—more food, better food, or both.

2. Increased muscular exercise,—more work, more climbing and walking, or more play.

3. Increased elimination,—more bathing, more massage, more water-drinking. In many cases a weekly or semi-weekly Turkish bath will be found a valuable adjuvant.

As a temporary resource, in case of run-down constitutions, to quickly replace lacking elements, much needed to prevent further waste, and for structural repairs, which it is now the whole aim to initiate, the following modification of a suggested physiological "tonic" may be resorted to with excellent results:—

℞ Calcii carb. (C. P.),	
Calcii phos. (C. P.),	āā ʒij.
Sodii phos. (C. P.),	ʒj.
Ferri pyrophos. (C. P.),	gr xv.
Potass. bicarb. (C. P.),	ʒj.
Sacch. lactis,	℥ss.

M. Ft. capsulæ no. lx.
Sig.: One to three capsules to be taken with each meal.

The vehicle is intended to better distribute the materials. They are thereby rendered much more soluble, and hence more surely assimilable.

Among the proprietary preparations which are worthy of mention are the Wheat Phosphates, Crystalline Phosphates, and some others of similar character. They are not remedies in any

other sense than that they are nutritives in readily assimilable form.

(*c*) *The Latest Treatment for Phthisis.*—It is really pathetic to witness the enthusiasm with which those who put their faith in germicides exclaim, as each new bacillus-annihilator is announced, that the bacillus tuberculosis must surely go; because, in the end, after fostering cruelly false hopes in the hearts of the coughing and wasting millions, they are all obliged to listen to the bitterly hopeless refrain:—

> "The bacilli may come and the bacilli may go,
> But phthisis goes on forever!"

But why be content with plain hot air when hot hydrogen, nitrogen, and carbonic acid, or, better still, hot *nitrous oxide* and *hot oxygen*, or various mixtures of these gases, could be availed of with equal facility and tenfold more effect?

It is to be hoped that this newest of the new treatments for the universal scourge will prove less fatuitous than its various predecessors. For it seems that a goodly number of bacilli have successfully resisted the onslaught of choke-damp and marsh-gas, of intra-pulmonary injections of phenic acid and bichloride; and they continue to flourish and revel in the very face of cod-oil and hypophosphites; in spite of the Adirondacks, Colorado, and California—even in defiance of hot water and chopped beef. Nevertheless, the bacillus must go!

Most of the powerful germicides act beautifully, as regards the germs, but are not absolutely reliable unless pushed to a degree that seriously endangers the life of the patient. Thus far no disastrous results have been reported from the use of Dr. Weigert's hot-air treatment. It is certainly more rational than sulphuretted hydrogen; safer than cavity-washing or intra-pulmonary poisoning at the point of the hypodermic needle, and far more sociable and less expensive than climatic banishment.

But, badinage aside, the hot-air treatment of phthisis is based on the plausible theory—not yet a thoroughly satisfactory demonstration—that heat is inimical to the vigor and vitality of the bacillus tuberculosis. This parasitic germ is said to flourish best at about 99° F. At 101.5° F. it is very much weakened, and at 107.5° F. it ceases to develop. At from 140° to 212° F. the destruction of the bacilli is complete; and yet it is found

that the human respiratory organs can tolerate, with perfect impunity, a temperature very much above this limit, if care be

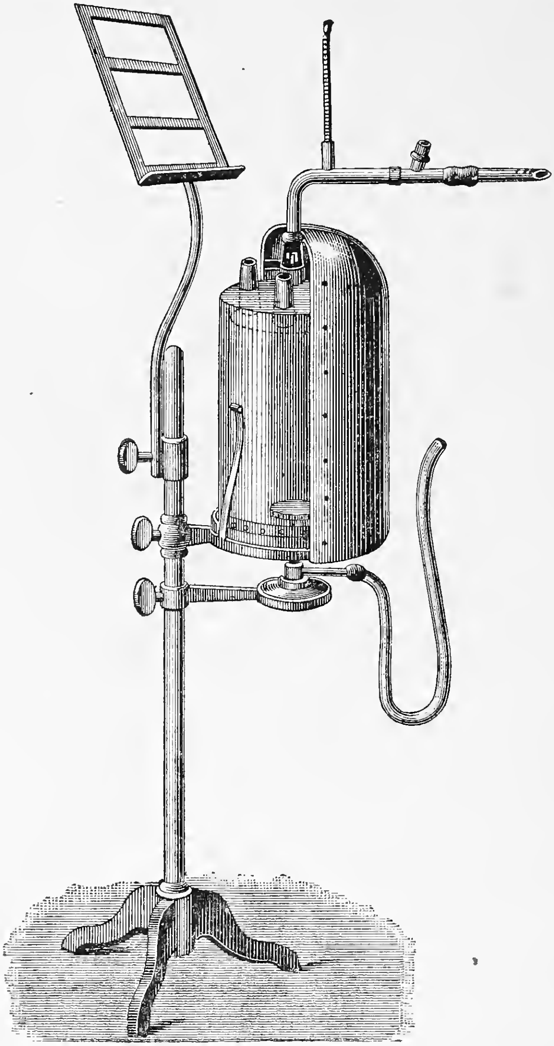


FIG. 21.—WEIGERT'S HOT-AIR APPARATUS.

It consists of a stand, with burner, asbestos shield, reading-desk, heating cylinders, inhaling tube, with mouth-piece, and a thermometer for regulating the temperature. [The cut represents the original form of apparatus. The form has now been somewhat modified and improved.]

taken to make the heated air perfectly anhydrous or dry. By actual experiment the temperature, in several instances, has

been gradually increased until it has exceeded 480° F., without injurious effect upon the patient.

Extravagant reports are being published and extravagant hopes are being indulged as to the attainable results of this novel treatment; but, query—heated atmospheric air becomes highly rarefied, and, in exact proportion to its rarefaction, *cheats the patient of his normal supply of oxygen.* Certainly, the latter gas, substituted for common air, would prove even more effective at a much lower temperature. Oxygen, at ordinary temperatures, is a powerful antiseptic and disinfectant; inferentially, *hot* oxygen would be tenfold more so. This being theoretically and practically true, hot oxygen must eventually supersede hot air as a treatment for phthisis.

The required apparatus is neither extensive nor complicated.

As yet no apparatus adapted to the administration of hot oxygen, or other factitious air, has been devised; but experiments, which will doubtless supply this want, as it naturally arises, are now in progress.

(*d*) *Applications to Surgery.*—There is unquestionably a considerable field for the utilization of the gases in surgery. This will be apparent from even a very cursory study of the experiments of our author, made in connection with his extensive surgical practice.

Of the various gases used, oxygen overshadows all the others as regards its applicability and importance.

As suggested by Ducroy, no surgeon should venture to perform a severe or capital operation, involving the use of anæsthetics, without having at command a quick-working and reliable oxygen generator, or a cylinder of the compressed gas, ready for instant use. This precaution would effectually fortify him against possible danger from ether or chloroform narcosis, thus reducing the fatality from this source to a minimum; but, what is equally desirable, it would ward off the unpleasant and sometimes quite serious after-effects of anæsthesia. There is no good reason why the most profound anæsthesia should not be rendered as safe and insignificant, as regards danger to life and depressing reaction, as the giving of an ordinary dose of bromide or chloral.

In addition to this essentially prophylactic use in surgery, oxygen may be made an important adjunct, as a preparatory treatment before severe operations, especially in cases of ovari-

otomy, laparotomy, and lithotomy. By a few weeks of its intelligent exhibition, in connection with other rationally indicated tonic measures, many of these cases may be rendered safe and justifiable, which, without such preparatory invigoration, would surely prove fatal. Every surgeon meets with scores of cases in which he hesitates to operate, on account of the debilitated condition and unhygienic surroundings of his subject. Very many of these unpromising cases, in which operation is decidedly demanded, yet will seriously jeopardize the lives of the subjects through the unavoidable shock and exhaustion which operations always involve, by a timely appeal to this invigorating agent may be put in a condition which will render the ordeal comparatively, if not absolutely, safe, and therefore both justifiable and desirable. Certainly, a more intimate knowledge and more general use of the gas among operating surgeons would prove a boon to the practice. Dr. Marcy, of Boston, eminent as a surgeon and gynæcologist, has for some time past used a spray of warm oxygen, in his laparotomy and ovariotomy cases, to the exclusion of all other antiseptic procedures, and reports the most gratifying and satisfactory results. This is a decided advance in antiseptic surgery, and when these facts shall have been more widely disseminated it will be strange indeed if oxygen, both as a prior constitutional treatment and a reliable safeguard in case of anæsthesia, and as a restorative after severe operations, as well as an antiseptic spray during operations, is not better appreciated and much more extensively used in all our large city hospitals, where facilities for its prompt preparation and exhibition are so comparatively abundant and so available.

Carbonic acid, nitrogen, and hydrogen each has its province in surgical practice,—limited, perhaps, but undeveloped, and hence yet indefinable. Each can be made available, to some extent, as adjuncts to other treatment, as modifiers of the influence of oxygen, and as assuagers of pain.

Nitrogen monoxide has a still wider field. In dental surgery it has already superseded all other anæsthetics, and its applications in other departments of surgical procedure are gradually becoming better appreciated.

(*e*) *As an Aid to Athletic Culture.*—When Lavoisier demonstrated that oxygen was a muscle-hardener, and that it so "toughened" the flesh of the animals experimented on that, on account of this toughness, they became unfit for food, he gave

the key-note to a world of practical application. It seems there were no ears at hand acute enough to catch its full meaning, therefore no practical application worthy of the name has ever been made. The inferences were plain and unmistakable; but even yet no scientific authority has had the astuteness, or the temerity, or perhaps the enterprise, to announce these inferences in the face of this intensely commercial age.

But the culture of athletics is being revived. Base-ball, the regatta, the ring, and the turf are every season commanding more and more attention. But the professional acrobats, athletes, and pugilists have practically and unaccountably overlooked, or but half availed themselves of their principal ally. Muscle-culture by the ordinary means of exercise, friction, kneading, beating, massage, and bathing—all chiefly valuable in proportion as they contribute toward increased oxygenation—has been pursued with a zeal that has enabled it to take rank as a semi-science. So, too, the dietary of men and animals in training for severe physical tests has been made a very thorough study. Every pugilist, pedestrian, cyclist, oarsman, wrestler, base-ballist, and acrobat has his professional trainer, who looks after and dictates for him, even to the most unimportant minutiæ of his daily physical habits and bodily hygiene—his food and drink, exercise and sleep; his rubbing, beating, and bathing; yet none of them have half appreciated, or in any practical degree utilized this genuine and incomparable source of vital culture. It is so rational and so directly in harmony with Nature's own methods that it is fairly self-suggesting. It is more than surprising that, through suggestions from the medical profession, it has not been turned to the fullest practical account by sporting devotees everywhere.

The teachings of physiology leave no doubt on this point. The aid is available. Given any two athletes, physical contestants in the ring, or horses on the track, equal as to physical development and alike as to all conditions and surroundings, except that one of each pitted pair shall have been thoroughly and scientifically pre-fortified by the muscle-hardening and vital-toning influences of oxygen, while the other lacks only this, the one thus prepared—case-hardened, as it were—is as sure to outwind his opponent and win the contest before them, whether it be wrestling, rowing, running, batting, or boxing, as the morrow's sun to shine.

This is no chimera since the practical test is easily applied.

(*f*) *Varying Conditions of Oxygen.*—The varying conditions of oxygen and the effect of these conditions on its value and results, used as a therapeutic means, is a theme worthy of careful study.

Faraday gives us a table showing the magnetic and diamagnetic intensity of the various gases. According to that table oxygen is the most magnetic of all the gases, as is iron of metals. The figures, as he gives them, are as follow:—

Oxygen, in magnetic intensity, ranges from 17.5 down to	3.4
Atmospheric air, magnetic intensity,	3.4
Olefiant gas, " "	.06
Nitrogen, " "	.03

Hydrogen has a diamagnetic intensity of	0.1
Ammonia [NH_3] " " "	0.5
Cyanogen [NC_2] " " "	0.9

It will be seen that oxygen has a wider range of variation than any of the other gases cited.

In none of the experiments thus far described has there been the slightest allusion to this condition. The only suggestion bearing upon it, in any way referred to, is the degree of condensation or compression to which the gas used has been subjected.

Thus, quiescent or atmospheric oxygen is oxygen at its minimum or initial tension or pressure, viz., that of one atmosphere. If the pressure be increased to two or four atmospheres its physical tension is certainly multiplied by two or four, as the case may be. But it does not follow that its magnetic tension has been multiplied in the same proportion.

From Richardson's experiments, elsewhere cited, it is evident that quiescent or normal oxygen may exist in various degrees of activity, or may be said to have widely varying degrees of vital worth. He proved that pure oxygen inhaled by an animal is only about 25 per cent. of it absorbed. Hence, 75 per cent. of it is exhaled, not in a pure state, but contaminated with carbonic acid, ammonia, traces of some other hydrocarbonaceous and nitrogenous compounds, and also by possible ptomaines, the chemical nature of which is not yet well understood. Collecting this exhaled oxygen and carefully purifying it from all the animal emanations imparted to it in the process

of respiration, so that by every chemical and physical test it is absolutaly pure oxygen, it nevertheless *fails to support life in warm-blooded animals. They die in it, as if suffocated in hydrogen, or other non-respirable gas.* It is evident that it has lost some essential property. What can this property be, if not either magnetic intensity or *ozone?* And if it be magnetic tension, do other influences than animal respiration interfere with or modify it? No doubt they do. In view of these subtle and unexplained conditions, experiments with stale or compressed oxygen may be never so ingenious and curious, they are not, therefore, scientifically conclusive. As a rule, they are no more nearly related to science than are caricatures to art. They are interesting and ingenious, to some extent, but they prove absolutely nothing of value. After an animal has exhaled into a closed receiver of oxygen for a certain time, what is the magnetic tension of the contained mixture of ammonia, carbonic acid, expired oxygen, ptomaines, etc.? Nobody knows; nobody has even inquired. The animal has convulsions, or dies, as the case may be. What is it that proves fatal? Is it the presence of animal emanations, of deadly ptomaines or leucomaines? Or, in view of the foregoing, are we not led to infer that it is partly the absence of that essential condition of oxygen which, perhaps, gives it all its vitality—its magnetic or combining force? These are questions yet to be solved, possibly, by some professional Morse or Edison, who will, perhaps, one day give us an *aëro-magnetometer*, and who will be able to tell us how to compute the real or vital value of a given sample of oxygen or other gas, just as they now estimate the quantity, quality, and resistance of electrical currents, in volts, ohms, and ampères. Who can assure us that oxygen compressed to one hundred and fifty atmospheres, or even to fifty, in a steel or iron cylinder, is not thereby disturbed as to its magnetic condition, so that it is thenceforth too low down in the scale of magnetic tension to afford anything like its normal vital value, or to result in other than negative and unsatisfactory tests? And who shall tell us how to restore this emasculated gas to its pristine virility?

Evidently the profession is yet merely coquetting with a vast subject; barely conning the alphabet of the intricate scientific principles involved in the study of widely distributed, incessantly active, and all-powerful elements.

Therefore, let us not be content with what has been done, but continue to press investigation until this fruitful field shall be made to yield its fullest possible fruition.

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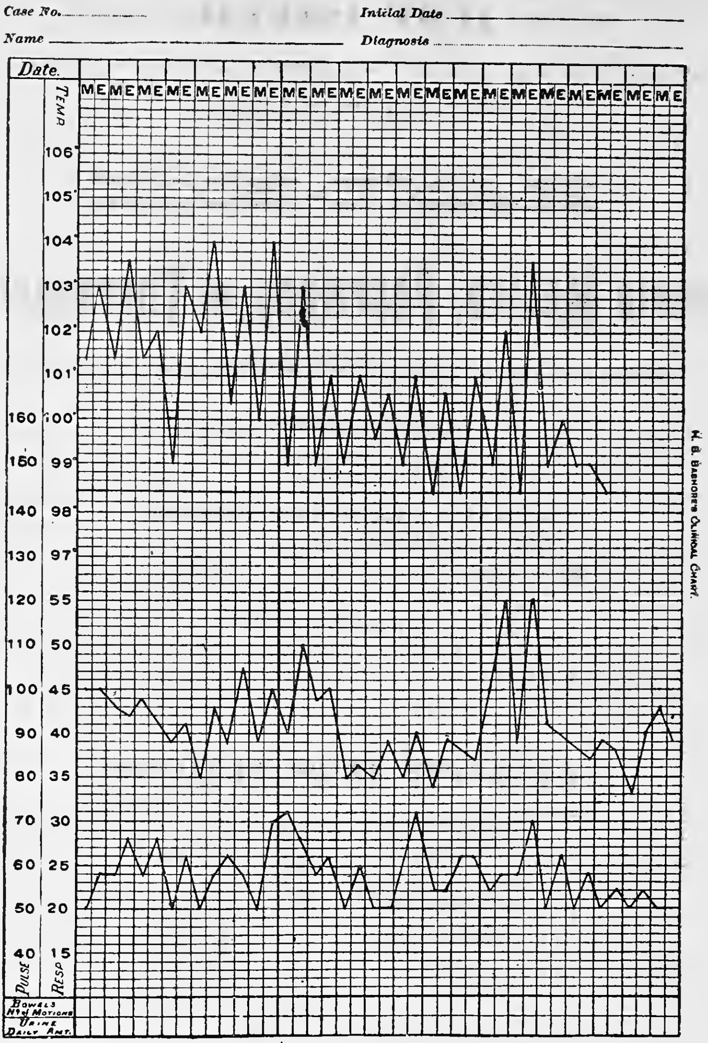

Case No.
Initial Date
Name
Diagnosis
Date.
TEMP
PULSE
RESP
H. B. BASHORE'S CLINICAL CHART.

THE CLINICAL CHART IN PRACTICE.

The following extract from an article by a physician in active practice well illustrates the necessity and value of such a chart:—

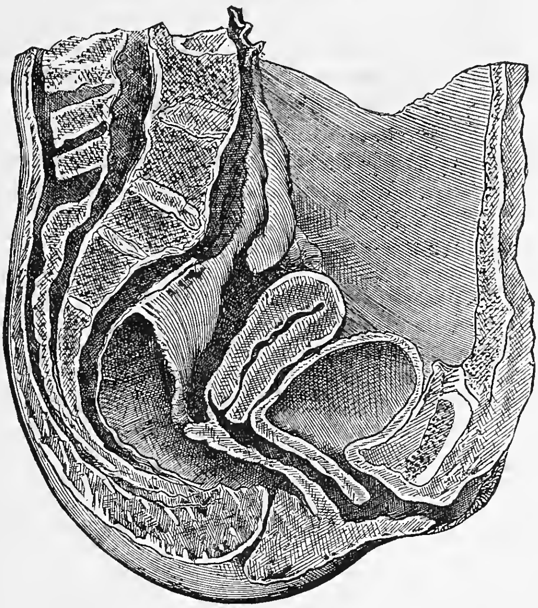
"A somewhat general inquiry among physicians in private practice has developed the existence of the fact of a lamentable indisposition to use the thermometric sheet at the bedside of the private patient. The very considerable advantages of a careful recording of the temperature and other important manifestations of disease would seem sufficient to bring about a different condition of things than that stated. To the physician in hospital practice, the temperature, pulse, and respiratory records are regarded as indispensable, not alone to a careful recording of the course and nature of the disease, but as well to the intelligent treatment of the same. Why should they not be appreciated to nearly an equal degree in private practice? There is, admittedly, a difference between private and hospital practice in the necessity for so faithful a recording of all the symptoms in the former as in the latter. Yet in actual experience the divergence is made too great, and the rich field of observation at the bedside of the home is permitted to go to waste. Observation will quickly unfold the fact that our medical journals are too sparse in papers that have attached to them any very trustworthy importance; and this is by reason of failure to record day by day the phenomena of disease, and the almost universal reliance on general statement and unsupported conclusions. This is inapplicable to reports of cases occurring in hospitals. In these institutions, each bed has its clinical chart, on which, daily or more frequently, are recorded the course and treatment of the disease. A word picture is thus drawn whose service to the attending or consulting physician is incalculable. Thus it is, mainly, that conclusions drawn from hospital practice are more valuable and reliable than those drawn from the almost uniformly unsystematic and imperfect study of private cases.

"Out of a large number of physicians to whom the writer put inquiries, only two or three were found who at the bedside of a private patient made anything like unto a systematic recording of the temperature, pulse, respiration, defecation, urination, and treatment of disease. Obviously this rarity is coincident with an inability to definitely define the course of the disease to consultant, in periodical, or in clinical society. Memory with the best is untrustworthy, and it proves surprisingly fickle as we pass from patient to patient, from scene to scene, with the attending tendencies to distract the attention and interfere with the exercise of recollection.

"The physician has merely to give the clinical chart, in some one of its many and useful forms, a trial, and its advantages will loom up so forcibly before his view that he will wonder at his former blindness."

in the position and in the axis of the womb, are downward, or forward, or backward, or to one side. To these I shall now direct your attention.

FIG. 44.



NATURAL POSITION OF THE WOMB WHEN THE BLADDER IS FULL. AFTER BRIESKY.

RETROVERSION AND RETROFLEXION OF THE WOMB.

By a retroversion of the womb, we understand a backward tilting of the fundus towards the sacrum, and an advance of the cervix towards the pubes—that is to say, it is a posterior inclination of the body of the womb without any bend in its axis. By a retroflexion of the womb is meant a backward bending of the womb upon itself, the fundus upon the cervix posteriorly.

These displacements are generally due to the increased weight and size of the womb, which its ligaments and other supports cannot sustain, and to a loss of tonicity in the uterine

PERPETUAL CLINICAL INDEX

—TO—

MATERIA MEDICA, CHEMISTRY, AND PHARMACY CHARTS.

By A. H. KELLER, Ph.G., M.D.

Consisting of (1) the "Perpetual Clinical Index," an oblong volume; 9x6 inches, neatly bound in extra Cloth; (2) a Chart of "Materia Medica," 32x44 inches, mounted on muslin, with rollers; (3) a Chart of "Chemistry and Pharmacy," 32x44 inches, mounted on muslin, with rollers.

	United States.	Canada (duty paid).	Great Britain.
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Read the Following Description and Explanation of the Work:

In presenting the objects and advantages of these Charts and "Perpetual Clinical Index" it becomes necessary to state that the Author's many years' experience as a physician and Pharmacist enables him to produce, in terse language, a volume of facts that must be of inestimable value to the busy physician and pharmacist, or to any student of either profession. He has endeavored to describe all that have borne investigation up to date.

The system will prove to be of great value in this, that so little labor will be required to add new investigation as fast as may be gathered from new books, journals, etc. The classification is alphabetical and numerical in arrangement, and serves so to unite the various essentials of Botany, Chemistry, and Materia Medica, that the very thought of the one will readily associate the principal properties and uses, as well as its origin.

The **"MATERIA MEDICA" CHART,** in the first place, aids at a glance: 1st, Botanical or U. S. P. Name; 2d, The Common Name; 3d, Natural Order; 4th, Where Indigenous; 5th, Principal Constituent; 6th, Part Used—herbs, leaves, flowers, roots, barks, etc.; 7th, Medicinal Properties—mainly considered; 8th, The Dose—medium and large.

On this Chart there are 475 first names; Section A. is numbered from 1 to 59, each section commencing with the capital letter, and having its own numbers on both left-hand and right-hand columns, to prevent mistakes in lining out, all in quite large type. In the centre of the Chart, occupying about 6 inches in width, is a term index of common names. In the second column of Chart, like this:

Aconite Leaves, ... 4 A.

Then by reference to 4 A in first column, you there find the Botanical or U. S. P. Name. On this Chart is also found a brief definition of the terms used, under the heading "Medicinal Properties."

The **"CHEMISTRY" CHART** takes in regular order the U. S. Pharmacopœia Chemicals, with the addition of many new ones, and following the name, the Chemical Formula, the Molecular Weight, and next the Origin. This is a brief but accurate description of the essential points in the manufacture: The Dose, medium and large; next, Specific Gravity; then, whether Salt or Alkaloid; next, Solubilities, by abbreviation, in Water, Alcohol, and Glycerine, and blank columns for solubilities, as desired.

Alkaloids and Concentrations are tabulated with reference numbers for the Perpetual Clinical Index, giving Medicinal Properties, Minute Dose and Large Dose For example, Alkaloids and Concentrations:

A.	Medicinal Properties.	Minute Dose.	Large Dose.
(a) Aconitine.	Narcotic and Apyretic.	1-500 gr.	1-16 gr.

Following this, Preparations of the Pharmacopœia, each tabulated. For example:

TINCTURAL.

Tinctura.	Drug.	Amount.	Alcohol.	Dose.
* Aconiti.	Aconite. Tartaric Acid, 60 † P.	5½ oz. to 24 gr.	100	1 to 3 drops.

* 60 Fineness of Powder as per U. S. P.
† P. Macerate 24 hours. Percolate, adding Menstruum to complete (1) pint tincture.

They are all thus abbreviated, with a ready reference head-note.

Next, Thermometers, Metric Table of Weights, Helps to the Study of Chemistry, Examples in Working Atomic Molecular Formulæ. Next, Explanation of Terms Used in Columns of Solubilities, List of Most Important Elements Now in Use, and Definitions or Terms Frequently Used in Chemistry and Pharmacy.

The **"PERPETUAL CLINICAL INDEX"** is a book 6 by 9 inches, and one-half inch thick. It contains 135 pages, divided as follows (opposite pages blank):

The Index to Chemistry Chart occupies two pages; Explanations, Abbreviations, etc., forty pages, with diseases, and with an average of ten references to each disease, leaving room for about forty more remedies for each disease. The numbers refer to the remedies used in the diseases by the most celebrated physicians and surgeons, and the abbreviations to the manner in which they are used. Eight pages, numbered and bracketed, for other diseases not enumerated. The Materia Medica, Explanations, Abbreviations, and Remedies suggested for, occupy twenty-six pages. For Abbreviated Prescriptions, seventeen blank pages. Then the Index to Alkaloids and Concentrations. These, already enumerated, with their reference, number six blank tabulated pages, for noting any new Alkaloids and Concentrations. Then the Chemistry Index, giving the same number as on Chart, with Name, Doses, Specific Gravity, Salt or Alkaloid in the same line, as for example:

Name.	Doses.	Specific Gravity.	Salt or Alkaloid.	Memoranda.

This Memoranda place is for Physicians' or Pharmacists' reference notes; and with the addition of several tabulated blank pages, in which to add any new chemical, with doses, etc. The remaining sixteen pages for Materia Medica Index, leaving blanks following each other for new names and reference numbers.

To show the ready and permanent use of the "Perpetual Clinical Index" of the "Chemistry" and "Pharmacy" Charts or Index in the book, suppose the Physician reads in a book or journal that Caffeine Citras is useful in the disease Chorea, and he wishes to keep a permanent record of that, he refers to the Chart, and if it does not already appear there, it can be placed opposite and numbered, and thereafter used for reference. But we find its permanent number is No. 99, so he will write down in the line left blank for future use in his book, in line already used, running parallel with other reference numbers in Chorea, the No. 99, and immediately under he can use the abbreviation in the manner in which it is given. Though years may have passed, he can in a moment, by referring there, see that No. 99 is good for Chorea. If failing to remember what No. 99 is, he glances at the Chart or Index. He sees that No. 99 is Caffeine Citras, and he there learns its origin and dose and solubility, and in a moment an intelligent prescription can be constructed.

 (F. A. DAVIS, Medical Publisher, Philadelphia, Pa.; U.S.A.)

Reviews of Massey's Electricity in the Diseases of Women.

"The author gives us what he has seen, and of which he is assured by scientific study is correct. In his brief description of the laws of electricity he has endeavored to present them in so concrete and practical a shape that the conscientious student is insensibly made to comprehend current proportions, as he would after prolonged mathematical study. He aims to make the medical user of electricity as intelligently familiar with this physical force as is now required of so many practical workers in its industrial applications. The author does not present electricity as an agent to be used in a routine manner in the treatment of uterine diseases, but rather as an agent of power and value in the treatment of these diseases. We are certain that this little work will prove helpful to all physicians who desire to use electricity in the management of the diseases of women."—*The American Lancet.*

"The great difficulty in successfully using electricity, and particularly the strong currents, after the method of Apostoli is want of expertness and skill and judgment in their application. While these qualities cannot be acquired entirely from books, the careful description of the necessary procedures as minutely explained by Dr. Massey is an aid that cannot be dispensed with. It is believed, therefore, that this book will help popularize among general practitioners the intelligent application of electricity in gynecology."—*The Medical Age.*

"To say that the author is rather conservative in his ideas of the curative powers of electricity is only another way of saying that he understands his subject thoroughly. The mild enthusiasm of our author is unassailable, because it is founded on science and reared with experience."—*The Medical Analectic.*

"This is the first attempt at a complete treatise on the electrical treatment of the diseases of women by an American author. The author has gone over the ground very thoroughly, and has placed his readers in the possession of many important facts. The electrical treatment of fibroid tumors and the various methods of employing electricity in gynecological work are fully set forth. The work is well written, exceedingly practical, and can be trusted. We commend it to the profession."—*Maryland Medical Journal.*

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—OR,—

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J. H. STUBBS, M.D., R. B. EWING, M.D.,
B. THOMPSON, M.D., S. STEBBINS, M.D.

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(F. A. DAVIS, Medical Publisher, Philadelphia, Pa., U.S.A.)

oughly macerated and soaked in fluid, and from which they are forced into the œsophagus during rumination or into the honey-comb bag during the intervals of rumination. It is evident, therefore, that the food contained in this pouch may undergo changes due to the movements to which it is subjected, the temperature, and the action of saliva and other fluids. The changes are, therefore, physical and chemical. The walls of the rumen, by their contractions and resulting movements, may exert a considerable amount of mechanical force on the aliments contained within it, although this has been greatly exaggerated. Nothing like trituration takes place, but simply thorough mixing of the new and old food together

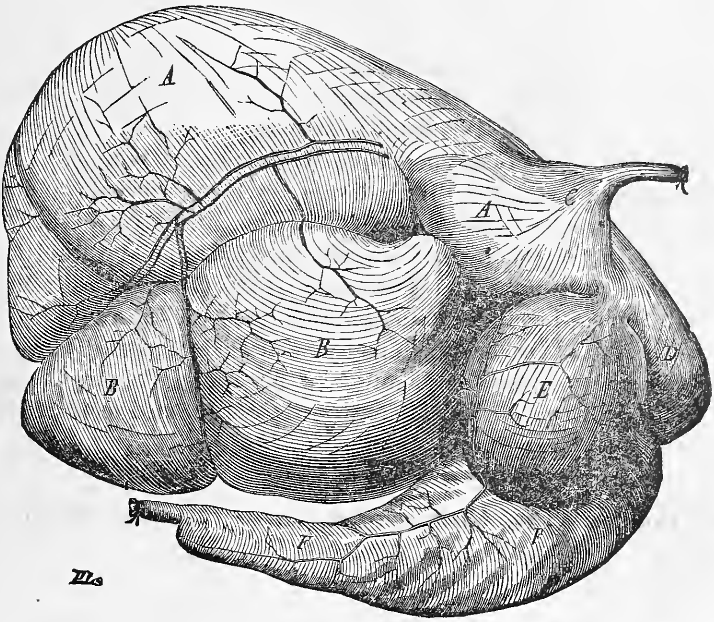

FIG. 153.—STOMACH OF THE OX. (*Colin.*)

A, rumen (left hemisphere); *B*, rumen (right hemisphere); *C*, insertion of the œsophagus; *D*, reticulum; *E*, omasum; *F*, abomasum.

and with fluid; consequently, it is not necessarily the portion of food which first enters the paunch which is the first to leave. The maceration which the food undergoes in the fluids of the paunch is especially marked in the case of grain and dry fodder, and is greatly assisted by the temperature of the organ.

The fluids contained in the rumen consist, in a great part, of water which has been drunk and a large quantity of saliva, which is swallowed with the first mastication and in the intervals of the act of rumination. The rumen has, however, no secretion of its own, since no secretory glands are found in its walls. Its reaction, as already stated, is generally

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GENERAL INDEX.

THERAPEUSIS.

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GENERAL INDEX.

THERAPEUSIS.

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attached by vessels to several small placentæ succenturiatæ. The clinical importance of multiple placentæ lies in the fact

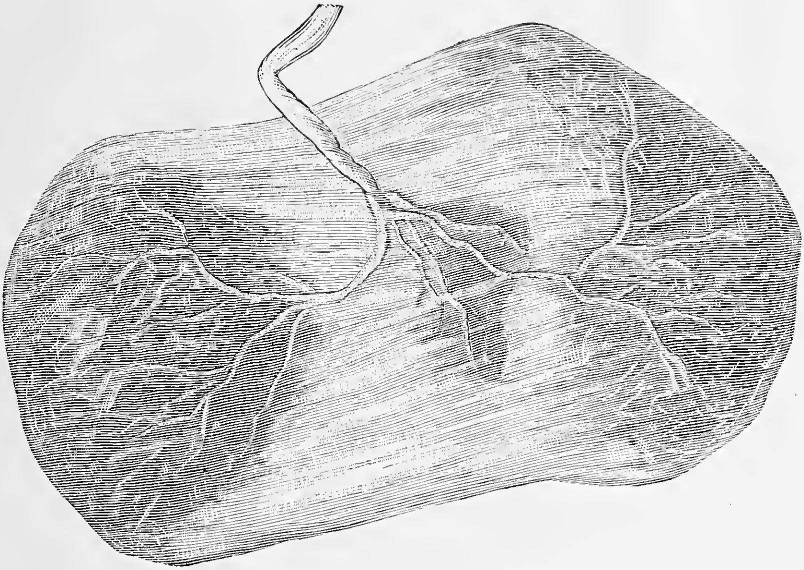

FIG. 2.—(*Annales de Gynécologie.*)

that one of these lobes may be retained in the uterus, while the other is expelled; and this accident is apt to occur if the attendant

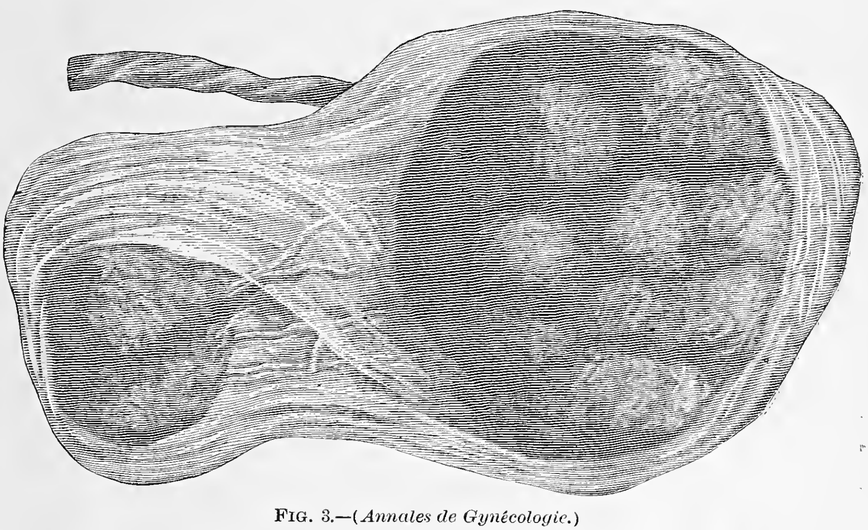

FIG. 3.—(*Annales de Gynécologie.*)

is in too great a hurry to remove the placenta. The practitioner should always carefully examine the placenta,—not only to see

under certain conditions; and it does not yet seem to have been satisfactorily demonstrated that the cyanosis is not due to some deleterious alteration of the blood.

Antipyrine.—The antipyretic action of this drug is so well understood that we find but little published concerning it during the year. Guitéras[38] considers it worse than useless to persist in the administration of antipyrine for many days in the course of the continued fevers of warm countries; and he has frequently found that its discontinuance was followed by a regular reduction of the temperature, with improvement of the other symptoms. He also noticed that the heart was weaker and the arterial tension less while antipyrine was being administered. Minot[38] gave antipyrine and thalline in 24 cases of typhoid fever, finding that 20–30 grs. of the former was needed. (For further notes of Minot's paper, see "*Thalline.*") Robison[39] failed to cut short typhoid fever by its use. Gradle[39] has found it valuable in doses of 4 grs. in the fever of dentition in infants, where there was a possible danger of convulsions. Scott[21] obtained good results from it in 2 cases of puerperal fever, as well as in 4 of malarial fever. An editorial writer[12] mentions the rapid reduction of a temperature 107.5° F. in a case of malarial fever, though he does not consider that the drug is any thing more than a simple antipyretic in this disease.

As regards phthisis, we find Patrick[39] declaring it very valuable in a few cases in which he has tried it, giving a dose every afternoon. Laache[35] made a special study of its action in phthisis, and found that it, as a rule, brought down the hectic fever very satisfactorily. Olikoff[35] confirms the reports in several journals concerning the hæmostatic action of antipyrine. In 6 cases of hæmoptysis he has employed a solution of 90 grs. in 6 ounces of water, used by inhalation, and has ordered 5–6 inspirations through the inhaler every $\frac{1}{2}$–1 hour, diminishing the hæmoptysis at once, and soon arresting it entirely. Snyers[22] has made trial of the comparative value of antipyrine, antifebrine, thalline and kairine, and much prefers the former. The defervescence, he says, is less rapid, and a subsequent rise slower and more regular; hence there is less abundant perspiration and less chilliness. Müller[22] agrees with this statement, but claims that the slower rise after antipyrine does not always take place, and is sometimes even more abrupt than after antifebrine.

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an *unbearably painful current* should be ascertained and noted. This may be compared with that necessary to produce contractions upon the healthy side.

The next step in the examination consists in *changing the rheophores to the binding-posts of a galvanic battery.* We can now ascertain the number of cells or milliampères (which is preferable) required to produce the different varieties of contractions (enumerated in the table designed for record) of muscles in homologous regions of the right and left sides. Each nerve which is impaired should be tested first; and the muscles

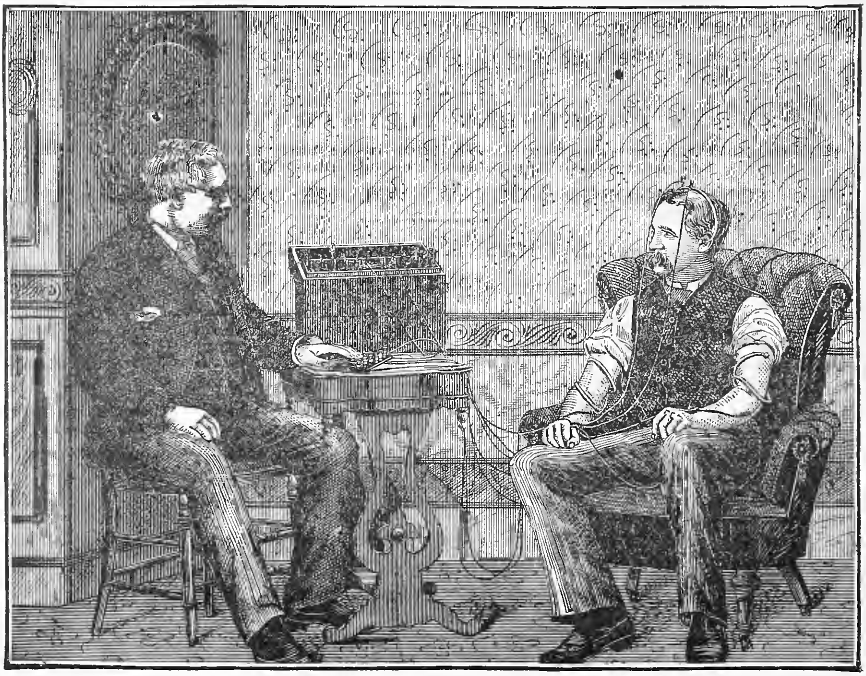

FIG. 61.—THE AUTHOR'S DIAGNOSTIC KEY-BOARD AS APPLIED IN ACTUAL USE.—The spring electrodes are represented in the cut (for the purpose of illustration) as applied to the facial, ulnar, and musculo-spiral nerves of each side. If he so chooses, the operator can have his case-book on a stand at his right, for recording his observations as they are made.

supplied by it should be tested afterward. The strength of the current employed should be ascertained by throwing a galvanometer into the circuit (when extreme accuracy is desired); by so doing, a comparison of the nerve- and muscle-reactions of the two sides can be based upon conditions which are exactly alike.

When we have completed the steps indicated by the chart prepared for the assistance of the practitioner (page 191) we are in possession of certain facts which may be of great practical value as regards both diagnosis and prognosis:—

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OF THE

NOSE AND THROAT

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BY

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The next page is a specimen from the work itself.

Of the three acids mentioned, chromic acid is by far the most satisfactory for posterior applications. Nitric acid is not sufficiently safe, while glacial acetic acid requires too many applications.

When an application is to be made, the instrument is adjusted so that the curved tip will take the proper direction on emerging, and the end of the rod is protruded. The tip is heated slightly to the fire of a match, and dipped among the crystals of the acid, then allowed to re-enter the tube. Enough of chromic acid will have adhered to the rod for the application. The tube being passed through the nasal cavity as far as the hypertrophy, the rhinoscope, held with the left hand, is placed in position, and the parts are illuminated. The location of the tube being ascertained, its point is placed against the side of the growth, and the spring is pressed upon. This forces the acid-covered point to emerge, the bend causing it to apply itself against the growth. By now drawing the instrument out a short distance, the application can be made more effective, the point thus parting with all its acid on the hypertrophied membrane as it rubs against it. The pressure on the spring being then released, the point disappears in the tube, and the instrument can be withdrawn. A solution of bicarbonate of soda, used posteriorly with the atomizer, is always indicated after this operation, to neutralize any excess of the acid that might have remained on the membrane, and to limit absorption. Four or five applications of this kind generally cause marked shrinkage of a moderate-sized growth.

Galvano-cautery can also be used in the same manner by introducing the cautery knife *d* (Fig. 33) instead of the acid application. The loop is introduced cold and applied against the side of the growth. Its position being ascertained with the rhinoscope, the circuit is closed, the handle being at